Cortical Activation During Robotic Therapy for a Severely Affected Arm in a Chronic Stroke Patient: a Case Report

Satoru SAEKI, Yasuyuki MATSUSHIMA and Kenji HACHISUKA

Department of Rehabilitation Medicine, School of Medicine, University of Occupational and Environmental Health, Japan. Yahatanishi-ku, Kitakyushu 807-8555, Japan

Abstract: The use of robotic-aided therapy in a patient with residual damage from a previous stroke was an attempt to improve function in a moderate to severe hemiparetic arm. Cortical activities associated with motor recovery are not well documented and require investigation. A chronic stroke patient with a severely affected arm underwent a robotic-training program for 12 weeks. The robotic-aided therapy improved motor control and spasticity in the proximal upper-limb. An increased oxygenated hemoglobin level was observed at the motor-related area in the affected hemisphere. A 12-week robotic-aided training program used in a chronic stroke patient demonstrated elements of motor recovery, and was also associated with direct activation of the affected hemisphere.

Key words: stroke, robotics, motor recovery, cortical activation.

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Introduction

Many research groups have developed robotic devices for upper-limb rehabilitation after stroke [1], such as MIT-Manus [2], MIME [3], NeReBot [4], and Bi-Manu-Track robotic arm trainer (AT) [5, 6]. Even when stroke patients were in a chronic state, the robotic-aided therapy improved moderate or severe hemiparesis in the arms to some extent [7, 8]. Although there are some clinical advantages evident with robotic therapy, the task specificity and related evidence such as cortical change during robot-aided training remain unclear.

In this case study, we investigated whether robotic training of the affected arm in a chronic stroke patient would lead to an increase in cortical activity in addition to the evident motor recovery.
Case Report

A 48 year old, right handed housewife without vascular risk factors was admitted to the hospital because of a sudden onset of headache and right hemiparesis. A neurologic examination showed severe right hemiparesis and anomic aphasia (disorder of naming), and computed tomography of the brain revealed left putaminal hemorrhage (Fig. 1). She received conservative therapy and comprehensive stroke rehabilitation which consisted of physiotherapy, occupational and speech therapy. For her hemiparetic upper limb, conventional rehabilitation that consisted largely of compensatory training of the nonpareteic arm was performed. Her right hemiparesis and aphasia improved to some extent, but the hemiparetic upper limb remained limited. After a two month length of stay in our hospital, she was discharged to her home and was able to care for herself and ambulate with an ankle foot orthosis. Additionally, she received outpatient rehabilitation service twice a week for maintenance of the regained motor function.

![Brain CT scan at onset shows the left putaminal hemorrhage.](image)

Two years after the onset of hemiparesis, she received robotic aided arm therapy. Her baseline data were as follows: 1) Motor Assessment Scale (MAS) [9, 10], upper-arm function 2 (lying, hold extended arm in elevation for 2 sec.), hand-movements 0 (no movement), and advanced hand activities 0 (no movement); and, 2) Modified Ashworth Scale (AS) [11], elbow 3 (more marked increase in muscle tone), wrist and finger 4 (passive movement difficult).

Robotic aided therapy for the hemiparetic arm was performed by the Bi-Manu-Track robotic arm trainer (AT) for 20 minutes twice a week for 12 weeks (24 sessions) without any other intervention. The AT enabled the mirror-like practice of two movement cycles: forearm pro-supination and wrist flexion-extension (Fig. 2) [5, 6]. The patient sat at a height-adjustable table with her elbows bent at 90 degrees and with her forearms in the mid-position in an arm trough. Each hand grasped a handle; a strap held the paretic hand in place. Two computer-controlled
modes were selected: 1) passive-passive (PP), with both arms moved by machine; and, 2) active-passive (AP), with the nonaffected arm driving the affected side. Within one session, she practiced 150 (PP=50, AP= 100) of the forearm cycles, and 150 (PP=50, AP= 100) of the wrist cycles, for a total of 300 cycles.

![Bi-Manu-Track Arm trainer](image)

**Fig. 2.** Bi-Manu-Track Arm trainer (forearm pro-supination position).

We evaluated cortical activation during the patient’s robotic training in both the PP and AP modes during week eight by using an optical topography system (ETG-100, Hitachi-medico) noninvasively. For recording the optical topographic data, each 60 seconds of task period for AT training with 30 seconds of rest period before and after the task was consecutively repeated 3 times (Fig. 3). This system includes 10 light sources and eight detector probes and records cortical changes in oxygenated hemoglobin (oxyHb), deoxyhemoglobin (deoxyHb) and total hemoglobin. We used the oxyHb value as the marker for cortical activity because there was a task-related increase of the oxyHb levels without apparent changes in the deoxyHb levels. For quantification of activation, we calculated \(\Delta\text{oxyHb} = \text{oxyHb during task period} - \text{oxyHb during rest period} \) in each channel. Each topographic map was corrected to match the anatomic location of the optodes on the brain surface. The cortical activation map during the robotic aided arm training is shown in Fig.4. During the AP mode training, asymmetrical activation was observed in the region of the motor-related areas such as sensorimotor cortex, premotor cortex and supplementary motor area. There was no regional activity noted during the PP mode training.

After the completion of robotic intervention (12 weeks), the MAS score of the arm improved from 2 to 5 (sitting, lift extended arm in forward flexion at 90 degrees to body for 10 sec.), however the scores for the hand and fingers did not change. The AS score of the elbow changed from 3 to 2 indicating a slight increase in muscle tone, but the score of the wrist and fingers did not change.
Discussion

A 12-week program of AT training in a chronic stroke patient demonstrated motor recovery in the affected arm proximally rather than distally, and also was associated with activation of the region of the motor-related area in the affected hemisphere. To the best of our knowledge, there is no report of cortical activation of the stroke affected hemisphere being directly enhanced by robotic therapy for a paretic arm.

The AT works on more distal arm movements, and allows repetitive practice of passive and active bilateral forearm and wrist movement cycles. The case improvement noted proximally in the affected arm was consistent with other robots, such as MIT-Manus and MIME, which work on shoulder-elbow movement and promote the recovery of the proximal arm. The higher
treatment intensity (the greater number of repetitions) [12] and the bilateral approach (the nonaffected arm driving the affected side) [6] are the most likely explanation for the enhanced result from this patient's robotic training. Other studies without the use of robot devices reported activation of the cortex by an active and passive bilateral arm approach. Weissler et al [13] showed that passive and active hand movements of healthy subjects resulted in a similar activation of the corresponding sensorimotor cortical area. Correspondingly, functional imaging studies after stroke revealed an enhanced activation of blood flow in the ipsilateral sensorimotor area, and subsequent motor recovery of the affected extremity [14]. A pilot functional MRI study revealed that bilateral arm practice enhanced activation of the primary motor cortex when compared with unilateral paretic hand movement in the early recovery stage of two stroke patients [15].

This case emphasizes the potential benefit of robotic arm training in patients with complications from a chronic stroke state, in part because the AP mode training brought direct activation of the cortex in the affected hemisphere. Even given the apparent results, the intensity and length of robotic training necessary to achieve results remain an ongoing problem.

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References

慢性期脳卒中患者の重度片麻痺上肢に対するロボット補助訓練中の脳賦活効果：症例報告

佐伯覚，松崎康之，蜂須賀研二
産業医科大学 医学部 リハビリテーション医学講座

要旨：近年，中等度から重度の脳卒中片麻痺上肢に対するロボット補助訓練が試行されており，運動回復とそれに伴う脳賦活効果については検討がなされていない。今回，慢性期脳卒中患者の重度片麻痺上肢に対して12週間のロボット補助訓練を実施した。ロボット補助訓練により，片麻痺上肢の運動回復と筋性の改善が得られ，障害側大脳半球運動関連領域の酸化増加を認めた。慢性期脳卒中患者の片麻痺上肢に対する12週間のロボット補助訓練の結果は，障害側大脳半球の直接的な脳賦活効果とともに運動回復の可能性を示唆している。

キーワード：脳卒中，ロボット，運動回復，脳賦活，

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