Case Study

Safety and efficacy of robotic elbow training using the upper limb single-joint hybrid assistive limb combined with conventional rehabilitation for bilateral obstetric brachial plexus injury with co-contraction: a case report

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Abstract. [Purpose] Obstetric brachial plexus injuries are accompanied by co-contractions due to misdirection of regenerated nerve fibers. The result is inhibition of arm movement necessary for activities of daily living. Rehabilitation is important to prevent joint contracture and muscle atrophy in such cases. A single-joint hybrid assistive limb is a new wearable robot that can assist in elbow joint motion by detecting muscle action potentials on the upper limb surface. Inhibiting co-contractions due to obstetric brachial plexus injuries with this device may help with performance of activities of daily living. This study aimed to evaluate the safety and efficacy of using a single-joint hybrid assistive limb combined with conventional rehabilitation in a patient with obstetric brachial plexus injuries. [Participant and Methods] A 40-year-old male with bilateral obstetric brachial plexus injuries and co-contractions of the biceps and deltoid underwent rehabilitation training using the single-joint hybrid assistive limb 3 times a week for 12 sessions (4 weeks) in both upper limbs. [Results] The patient completed all 12 sessions of training using the single-joint hybrid assistive limb with no adverse events. Improvements in flexion strength in the left elbow, active flexion range of motion in both elbows, and functional tests in the right arm were observed. [Conclusion] Elbow training using the newly developed single-joint hybrid assistive limb combined with conventional rehabilitation can be performed without severe adverse events and may improve muscle strength, range of motion, and arm functions in adults with obstetric brachial plexus injuries and bilateral co-contractions of the deltoid and biceps muscles. Key words: Obstetric brachial plexus injury (OBPI), Upper limb single-joint hybrid assistive limb (HAL-SJ), Co-contraction

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INTRODUCTION

Recently, the incidence of obstetric brachial plexus injuries (OBPIs) has decreased to 0.9 cases per 1,000 live births with the increase in the rate of cesarean deliveries\(^1\). OBPI can cause upper extremity deficits in infants, ranging from mild injuries, which resolve completely, to severe and permanent disabilities\(^2\). Although the rate of spontaneous recovery is high, some patients experience disturbances in activities of daily living (ADL). Sometimes, OBPI is accompanied by cocontractions due to misdirection of the regenerated nerve fiber, such as cocontractions between the biceps and the deltoid and between the biceps and the triceps\(^3\)–\(^5\). Moreover, muscle weakness leads to restriction of active range of motion (ROM) in the arm experiencing OBPI. Rehabilitation, including ROM exercises, muscle training, and stretching, is important to prevent joint contracture and muscle weakness caused by incomplete paralysis and cocontraction in OBPI. However, no appropriate and particularly conservative rehabilitation training has been established for cocontraction due to misdirection of OBPIs. Furthermore, patients for whom good results cannot be achieved with conservative therapies, such as rehabilitation, may be treated surgically for cocontraction using nerve repair and other procedures\(^6\)–\(^7\).

The upper limb single-joint hybrid assistive limb (HAL-SJ; HAL-FS01, Cyberdyne, Inc., Japan) is a wearable robot that can assist in elbow joint motions by detecting bioelectrical signals (muscle action potentials) on the surface of the upper limbs (Fig. 1). This device has been clinically applied postoperatively to patients with diseases such as traumatic brachial plexus injury\(^8\),\(^9\) and spinal cord injury quadriplegia\(^10\). Kubota et al. reported the safety and feasibility of training using the upper limb HAL-SJ for patients with elbow flexor reconstruction after traumatic brachial plexus injury\(^8\),\(^9\). The HAL-SJ has the potential to be inhibiting cocontractions due to OBPI. Because this device has the potential to be inhibiting muscle contraction of the shoulder abduction during elbow flexion training. Therefore, we provided this device in a patient with OBPI by it is expected in this motor learning effect. Inhibiting cocontractions due to OBPI with this device is believed to be effective to improve ADL. This case aims to report the efficacy and safety of using the newly developed upper limb HAL-SJ combined with conventional rehabilitation in an adult patient with OBPI.

PARTICIPANT AND METHODS

A 40-year-old male (height 163.8 cm, weight 82.7 kg) sustained a bilateral OBPI at birth. He had obstetric brachial plexus palsy (C5, 6, 7 type) with cocontractions between the deltoid and biceps (Fig. 2). The left deltoid-biceps cocontractions presented more severe symptoms. The Medical Research Council (MRC)\(^11\) grade during the initial examination indicated the following muscle strengths on the right/left side: trapezius, 5/5; deltoid, 2/3; biceps, 2/2; triceps, 4/4; flexor carpi radialis, 5/5; palmaris longus, 5/5; extensor carpi radialis longus/brevis, 5/5; lumbricales, 5/5; and flexor digitorum profundus, 4/4. Needle electromyography at the initial examination revealed a denervation potential in the left deltoid, biceps, triceps, extensor indicis proprius, first dorsal interosseous (FDI), opponens pollicis (OP), pectoralis major, infraspinatus, right deltoids, and biceps. Grip strength was 17.5/12.5 kg on both sides. Passive ROM was normal in both upper limbs. He had no joint contractures of the shoulders, elbows, wrists, and fingers. Sensory examination revealed mild sensory disturbance at both C6 areas. ADL that involved use of the upper limbs were assessed. The patient had not undergone any surgical operations. However, he had been visiting the hospital regularly and had been taught self-stretches of the trunk, upper arm, and back by physical therapists. He sometimes received concentrated inpatient physical therapy.

Rehabilitation training with both elbow exercises using the upper limb HAL-SJ were implemented for 12 sessions 3 times.
per week (4 weeks) in an in-hospital setting (Fig. 3). At first, left upper limb HAL-SJ training was started continuously for 12 sessions, followed by right upper limb HAL-SJ training for 12 sessions. Elbow flexion exercises using the upper limb HAL-SJ were performed approximately 50–200 times per session in a seated position. An operator or a therapist handled the controller and supported the device throughout the elbow exercises. Although the number of times per session elbow flexion was performed using the upper limb HAL-SJ was gradually increased, the frequency was determined with consideration of the patient’s factors, such as fatigue, motivation, and health condition. The patient also received conventional rehabilitation such as ROM exercises, stretching, muscle training of both upper limbs and trunk, and self-exercises during the upper limb HAL-SJ training.

Any adverse events during the HAL-SJ training were carefully observed and evaluated during each session. The clinical evaluation at baseline and after all HAL-SJ training sessions included the Medical Research Council (MRC) grade of elbow flexion, the dynamometric test using a handheld dynamometer (HHD), active flexion ROM of the elbow joint, a simple test for evaluating hand function (STEF; Sakai Medical Corp., Tokyo, Japan)[12], and the Disability of the Arm, Shoulder, and Hand (DASH) questionnaire[13] without using the upper limb HAL-SJ. Evaluation using the HHD test was performed in accordance with the method described by Andrews et al.[14], with slight modifications as follows: The patient was placed in a supine position, with the shoulder in a neutral position, the elbow joint flexed to 90°, and the forearm in supination. The dynamometric sensor was positioned 5 cm proximal to the crease of the wrist, and the forearm was fixed manually by both hands of the examiner. We instructed the patient to perform maximal elbow flexion, and three measures were used to calculate the mean maximum elbow flexion power. Hand function and dexterity were assessed using the STEF[12]. The STEF was developed as a standardized battery for the simple and objective evaluation of the functional movement ability of the upper limbs, including the fingers. The DASH questionnaire was used to assess upper limb physical function. Lower DASH scores indicated better upper limb physical function.

This study was conducted with the approval of the Ethics Committee of the University of Tsukuba, Faculty of Medicine (H26-022) and was registered with the University Hospital Medical Information Network (UMIN) Clinical Trials Registry (UMIN000014336). The patient was informed about the aim and design of this study, and he provided written, informed consent.

RESULTS

The patient completed all 12 sessions (each for the left and right sides) of training using the upper limb HAL-SJ. No serious adverse events were observed during the upper limb HAL-SJ training. Improvements were observed in the results of the left HHD test, active flexion ROM of both elbows, right STEF, and the right DASH questionnaire after 12 sessions. No changes from baseline were observed in terms of MRC grade and right HHD testing after training with the upper limb HAL. Left STEF and left DASH scores were equal to or slightly worsened after 12 sessions. Table 1 shows the MRC grade, HHD test score, active flexion ROM of both elbows, STEF, and DASH questionnaire scores before and after the upper limb HAL-SJ training.

DISCUSSION

The newly developed upper limb HAL-SJ can be used for elbow training in adult patients with OBPI and bilateral co-contractions of the deltoid and biceps. No adverse events such as pain, excessive fatigue, or abrasion due to the device were observed after elbow training using the upper limb HAL-SJ.

After the training with the upper limb HAL-SJ combined with conventional rehabilitation, bilateral improvement was observed in the active flexion ROM of the elbow. Furthermore, improvements were observed in the left HHD test results.
Although it is difficult to determine the main effect of the therapy, it is believed to be the increased muscle strength due to the bilateral elbow flexion power gained from training with the upper limb HAL-SJ combined with conventional rehabilitation. Although the cocontractions did not disappear completely, the improved left STEF and DASH scores suggest that the upper limb HAL-SJ training inhibited the muscle activity of the deltoid, which is presumed to have contributed to the achievement of smoother arm motions. No change was observed in the MRC grade of bilateral elbow flexion muscle strength and the right HHD test results. Moreover, left STEF and left DASH scores were equal to or slightly worsened after 12 sessions. For these reasons, we considered the fatigue status of the patient, because the patient also received conventional rehabilitation in addition to HAL-SJ training. If only HAL-SJ training was performed, the results may have been different. When combined with conventional rehabilitation, it also may be that the number of HAL-SJ training sessions were implemented too frequently. Furthermore, there may be influences such as a difference in the degrees of cocontraction contralaterally. It is necessary to evaluate these after each session in the future and clarify the suitable number of sessions. It is also necessary to clarify the degree of OBPI and to indicate the type of injury. This is a future task because long-term efficacy was not assessed after HAL-SJ training in this study.

Once cocontraction develops in patients with OBPI, it does not subside because misdirection of the regenerated nerve fiber does not repair spontaneously anatomically. However, low muscle activity of the triceps during elbow flexion training with the upper limb HAL-SJ may stimulate the effect of motor learning to inhibit triceps activity in elbow flexion during ADL so that smooth upper limb motion and ADL improvement can be achieved. The muscle activities of the shoulder abduction muscle (Deltoid) were unknown during elbow flexion training using HAL-SJ, because electromyogram (EMG) study was not implemented in this study. Therefore, the inhibiting muscle activities of the shoulder abduction muscle (Deltoid) by HAL-SJ training were not clear. Consequently we consider that it need more EMG study about muscle activities of the shoulder abduction muscle (Deltoid) during elbow training using HAL-SJ in the future.

Although different from that observed in the present patient in terms of injury type, cocontraction due to misdirection of the regenerated nerve fiber in patients with OBPI often occurs between the biceps brachii and the triceps. In that case, when patients try to flex the elbow, both the biceps brachii and triceps contract, preventing smooth flexion and extension of the elbow, despite sufficient contraction force of the elbow, ultimately leading to ADL disabilities. We would like to conduct arm training with the upper limb HAL-SJ for these types of patients as well in the future, with high anticipation that smooth upper limb motions and improved ADL can be achieved by conducting elbow training limited to elbow flexion and extension using the upper limb HAL-SJ in these patients.

Elbow training using the newly developed upper limb HAL-SJ combined with conventional rehabilitation could be performed without serious adverse events in an adult patient with OBPI and bilateral cocontraction of the deltoid and biceps muscles.

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**Conflict of interest**

None.
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