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Case Report & Case Series

A newly developed upper limb single-joint HAL in a patient with elbow flexion reconstruction after traumatic brachial plexus injury: A case report

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ABSTRACT

We report a case in which elbow flexion exercises using the upper limb single-joint Hybrid Assistive Limb (upper limb HAL-SJ) were implemented in a patient 13 months postoperatively following elbow flexion reconstruction with intercostal nerve transfer after a traumatic brachial plexus injury. Treatment using the upper limb HAL-SJ was administered once a week for 10 sessions from 13 to 16 months after surgery. Exercises using the upper limb HAL-SJ supported elbow motion by detecting bioelectric signals through surface electrodes on the biceps and triceps brachii. No adverse events were observed during treatment with the upper limb HAL-SJ. Improvements in elbow flexion strength were observed during treatment. Treatment with the upper limb HAL-SJ can be performed safely and effectively following elbow flexion reconstruction by intercostal nerve transfer after a traumatic brachial plexus injury.

1. Introduction

Traumatic brachial plexus injury is a severe peripheral nerve palsy resulting in upper limb dysfunction. Intercostal nerve transfer represents one method of elbow flexion reconstruction and allows approximately 60 to 90% of patients to actively flex their elbow against gravity after surgery for brachial plexus injury [1–4]. The remaining patients can exhibit poor recovery of elbow flexion even after surgery. Although the known risk factors for poor recovery include age, duration of time between injury and surgery, and surgical technique, rehabilitation after surgery is also an important factor in long-term recovery [5]. As a promising rehabilitation method, biofeedback therapy has been reported to support re-innervation of the biceps brachii after intercostal nerve transfer [6]. Biofeedback therapy has been used to facilitate voluntary muscle contraction of the biceps muscle, replacing the original function of the intercostal nerve to innervate respiratory muscles [6].

The upper limb HAL-SJ is a wearable robot that can support elbow flexion and extension motion (Fig. 1a, b). The features of the upper limb HAL-SJ enable well-synchronized voluntary elbow motion by detecting weak muscle action potentials through surface electrodes on the upper arm (Fig. 1c), enhancing elbow flexion and extension motion even in patients with a grade 1 manual muscle test (MMT). We hypothesized that treatment with the upper limb HAL-SJ could potentially be a novel biofeedback therapy following intercostal nerve transfer for brachial plexus injury. This is the first report of the application of the upper limb HAL-SJ following intercostal nerve transfer surgery for brachial plexus injury, showing its safety and feasibility.

2. Case presentation

The patient was a 35-year-old woman. She sustained a left brachial plexus injury (C5, 6, 7 preganglionic injury), multiple facial fractures, brain contusion, and traumatic subarachnoid hemorrhage in a motor vehicle traffic accident. Three months after the injury, elbow flexion reconstruction including intercostal to musculocutaneous nerve transfer and accessory to suprascapular nerve transfer was performed because

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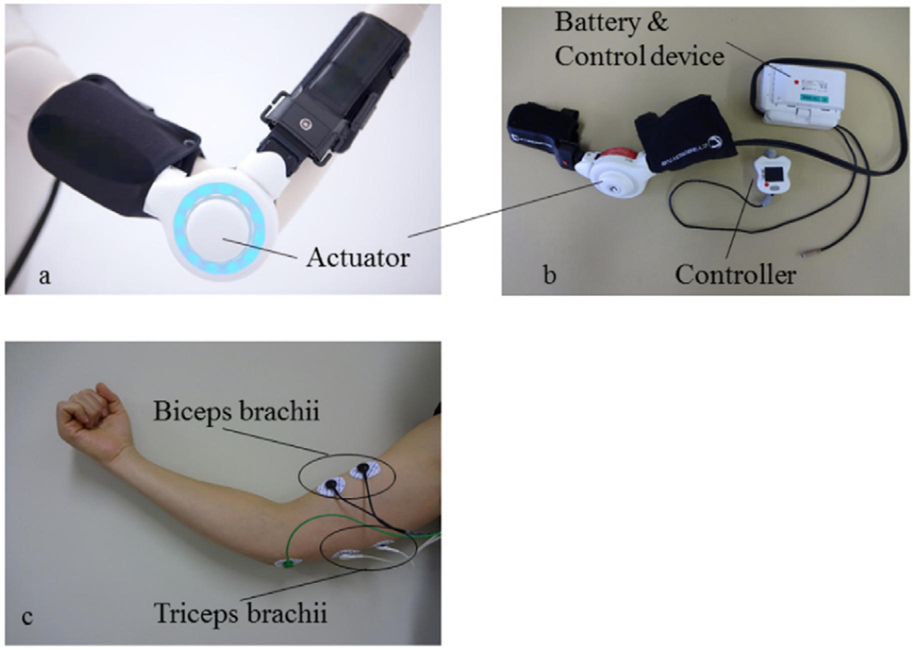

Fig. 1. a, b: Upper limb single-joint HAL (upper limb HAL-SJ). The upper limb HAL-SJ has the actuator (power unit) in the elbow joint on the lateral side. c: Surface electrodes on the biceps brachii and triceps brachii.

active elbow flexion showed no apparent recovery. Five months postoperatively, conventional electromyographic (EMG) biofeedback was started when muscle re-innervation (Medical Research Council (MRC), grade 1) was detected in her biceps brachii by needle EMG. Elbow flexion recovered to MRC grade 3 twelve months after surgery.

Elbow flexion exercises using the upper limb HAL-SJ (Suppl. Video 1) were initiated 13 months after surgery. Upper limb HAL-SJ exercises were performed once a week for 10 sessions as an outpatient. Elbow flexion exercises using the upper limb HAL-SJ were performed 50–100 times per session in a seated position (Fig. 2). A therapist operated the controller and supported the device during performance of the elbow exercises. The surface electrodes of the upper limb HAL-SJ were attached to the skin over the biceps and triceps brachii. Any adverse events during treatment with the upper limb HAL-SJ were carefully observed and collected at every session.

At the start of every session, the MRC grade, active flexion ROM of the elbow joint, elbow flexion 10-second testing, and dynamometric testing using a hand-held dynamometer (HHD) were evaluated without use of the upper limb HAL-SJ. The Disability of the Arm, Shoulder, and Hand (DASH) questionnaire was used to assess upper limb physical function.

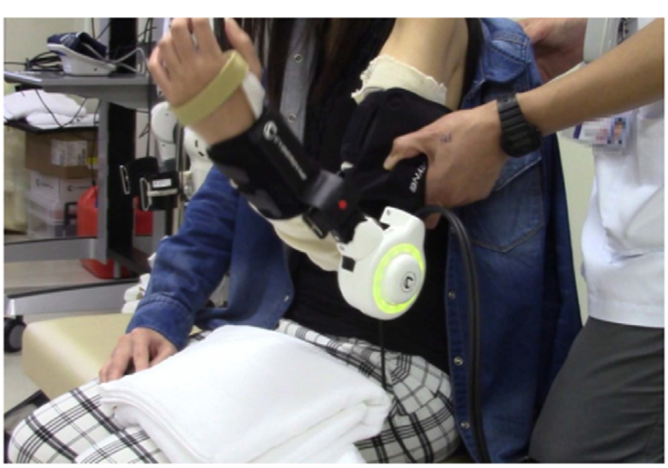

Fig. 2. Elbow flexion treatment using the upper limb HAL-SJ.

For elbow flexion 10-second testing, the number of repetitions of active elbow flexion that could be performed in 10 s was recorded. HHD testing was evaluated according to the method described by Andrews et al. [7] with slight modifications as follows. The patient was placed in a seated position with the shoulder in a neutral position, the elbow joint flexed to 90° (on the desk), and the forearm in supination. The dynamometric sensor was positioned 5 cm proximal to the crease of the wrist, and the forearm was fixed to the desk using a belt. We instructed the patient to perform maximal elbow flexion, and three measures were used to calculate the mean maximum elbow flexion power.

The patient completed all 10 sessions of treatment using the upper limb HAL-SJ with no adverse events. The treatment period using the upper limb HAL-SJ was from 13 to 16 months postoperatively. Remarkable improvements in elbow flexion power were observed after 10 sessions with the upper limb HAL-SJ, as indicated by improvements in MRC grade from 3 to 4 (Table 1). Active ROM in elbow flexion, DASH scores (Table 1), HHD testing, and elbow flexion 10-second testing (Fig. 3a, b, Suppl. Video 1) also improved after treatment with the upper limb HAL-SJ.

3. Discussion

In the present case, rehabilitation using the upper limb HAL-SJ following intercostal nerve transfer surgery for brachial plexus injury was performed without any adverse events, showing the safety and feasibility of this method of treatment.

Conventional EMG biofeedback therapy can be started with a grade 1 MMT with reinnervation of the biceps brachii 6–8 months after intercostal nerve transfer. Patients can learn how to control biceps muscle

Table 1
The results for MRC grade, active ROM in elbow flexion, and DASH score at baseline and after treatment.

	[a]MRC grade	[b]ROM of elbow flexion (°)	[c]DASH score
At baseline	[3] (good)	130	37.1
After the treatment	[4] (excellent)	145	21.6

[a] MRC: Medical research council grade.
[b] ROM: Range of motion.
[c] DASH: Disability of the Arm, Shoulder, and Hand questionnaire.

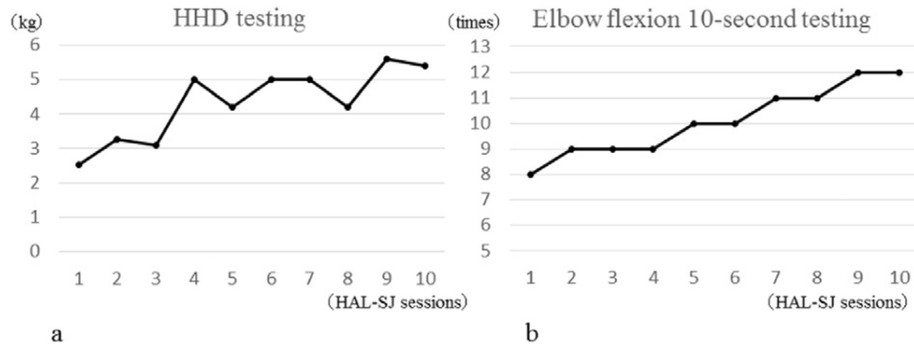

Fig. 3. a: Change in HHD (hand-held dynamometer) testing during upper limb HAL-SJ sessions. b: Change in elbow flexion 10 second testing during upper limb HAL-SJ sessions.

contraction in synchrony with an EMG wave on a monitor and EMG sounds from their biceps brachii recorded through a surface electrode, as a form of audiovisual biofeedback [8]. However, EMG biofeedback therapy alone cannot create voluntary elbow motion. In contrast, the upper limb HAL-SJ can assist elbow flexion triggered by muscle action potentials detected by surface electrodes. Assisted elbow joint motion can evoke sensory input from the elbow joint, possibly resulting in sensory feedback. The addition of sensory feedback from assisted elbow joint motion with the upper limb HAL-SJ may enhance the therapeutic effect of biofeedback therapy for brachial plexus injury patients.

In conclusion, the present case shows that treatment with the upper limb HAL-SJ is safe and feasible for elbow flexion reconstruction after brachial plexus injury. Although further exploration is needed to prove true efficacy, this is the first step towards the clinical application of the upper limb HAL-SJ for brachial plexus injury.

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.inat.2017.07.005.

Approval of the ethics committee

This study was conducted with the approval of the Ethics Committee of the Tsukuba University Faculty of Medicine and this study was registered with the University Hospital Medical Information Network (UMIN) Clinical Trials Registry (UMIN000014336).

Conflict of interest statement

A commercial party having a direct financial interest in the results of the research supporting this article has conferred or will confer a financial benefit on 1 or more of the authors. Y.S. is the CEO of Cyberdyne Inc., Ibaraki, Japan. H.K. is a stockholder of the company. Cyberdyne is the manufacturer of the robot suit HAL. This study was proposed by the authors. Cyberdyne was not directly involved in the study design; collection, analysis, or interpretation of data; writing the report; or the decision to submit the paper for publication. No commercial party having a direct financial interest in the results of the research supporting this article has or will confer a benefit on the remaining authors or on any organization with which the authors are associated (S.K., Y.H., Y.S., H.K., T.K., A.M., T.U., M.K., A.M., Y.H., and M.Y.).

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References

[1] D.C. Chuang, M.C. Yeh, F.C. Wei, Intercostal nerve transfer of the musculocutaneous nerve in avulsed brachial plexus injuries: evaluation of 66 patients, J. Hand Surg. [Am] 17 (1992) 822–828.
[2] B. Coulet, J.G. Boretto, C. Lazerges, et al., A comparison of intercostal and partial ulnar nerve transfers in restoring elbow flexion following upper brachial plexus injury (C5–C6+/−C7), J. Hand Surg. [Am] 35 (2010) 1297–1303.
[3] A. Nagano, N. Tsuyama, N. Ochiai, et al., Direct nerve crossing with the intercostal nerve to treat avulsion injuries of the brachial plexus, J. Hand Surg. [Am] 14 (1989) 980–985.
[4] N. Ochiai, Y. Mikami, S. Yamamoto, et al., A new technique for mismatched nerve suture in direct intercostal nerve transfers, J. Hand Surg. (Br.) 18 (1993) 318–319.
[5] N. Smania, G. Berto, E. La Marchina, et al., Rehabilitation of brachial plexus injuries in adults and children, Eur. J. Phys. Rehabil. Med. 48 (2012) 483–506.
[6] J.K. Terzis, V.K. Kostopoulos, The surgical treatment of brachial plexus injuries in adults, Plast. Reconstr. Surg. 119 (4) (2007) 73e–92e.
[7] A.W. Andrews, M.W. Thomas, R.W. Bohannon, Normative values for isometric muscle force measurements obtained with hand-held dynamometers, Phys. Ther. 76 (1996) 248–259.
[8] D. Kinlaw, Pre-/postoperative therapy for adult plexus injury, Hand Clin. 21 (2005) 103–108.