Electromyography effect of a new robotic biofeedback rehabilitation training with upper limb Hybrid Assistive Limb in patients with brachial plexus injury after elbow flexor reconstruction surgery

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INTRODUCTION: Traumatic brachial plexus injury (BPI) is a severe peripheral nerve palsy resulting in upper limb dysfunction. Intercostal nerve crossing-to-musculocutaneous nerve transfer (ICN-MCN transfer) represents one method of elbow flexor reconstruction and allows approximately 60–90% of patients with BPI to postoperatively actively flex their elbow against gravity (manual muscle testing; MMT grade 3). However, some patients present with poor voluntary elbow flexion postoperatively. Although several risk factors play a role in poor recovery, including age, the duration of time between injury and surgery, and the surgical technique, extended rehabilitation after surgery is also an important factor to consider. The upper limb HAL enables synchronized voluntary elbow motion by detecting the muscle action potentials through surface electrodes on the upper arm (Fig. 1). This study aimed to evaluate the electromyographically effectiveness of muscle re-education elbow flexion biofeedback training using the upper limb Hybrid Assistive Limb (upper limb HAL) following elbow flexion reconstruction for BPI.

METHODS: Nine patients (mean age 35.5 years, 8 men, 1 woman) with previous BPIs participated in this study. All patients' injuries related to traffic accidents. The types of BPIs were one C5-6 (upper type), one C5-8, and seven whole-type. All patients received elbow flexor reconstruction surgery (ICN-MCN transfer) for BPI. All nine patients underwent elbow flexion training using the upper limb HAL as out-patients once a week for the duration of one month. The mean starting time of HAL training from the time of elbow flexor reconstruction surgery was 7.4 month (range 5 to 9 months). All nine patients with ICN-MCN transfers presented with biceps MMT grade 1 due to reinnervation after surgery when they started upper limb HAL biofeedback training. Clinical evaluation included elbow flexion power and the mean postoperative months (POM) to achieve an improvement in elbow flexion power to MMT grade 3. This was evaluated before and after HAL, and at the final examination. Furthermore, in five of all nine patients, we measured muscle activity (mean amplitude) of the biceps at the times of MMT grade 1 and 2. Electromyographic evaluation included the measurement of biceps muscle activities using wireless electromyography (EMG) system (NORAXON, Scottsdale, AZ, USA) at the start of every session. The mean amplitude of biceps was measured during elbow flexion (MMT grade1 and 2) with/without HAL, 5 seconds of elbow flexion, and conventional biofeedback training. EMG data was analyzed and normalized by the maximal voluntary contraction (MVC) method. The Wilcoxon signed-rank test was used to evaluate the differences with and without HAL. Data were analyzed using IBM SPSS Statistics 24 (IBM, Armonk, NY, USA) and an α level was set to 5%.

RESULTS: The upper limb HAL training lasted for a mean of 24.8 ± 12.0 sessions (range 7 - 44). In all nine patients who presented with biceps MMT grade 1 after surgery, improvement in elbow flexion power to MMT grade 3 was observed in seven patients after upper limb HAL training; three patients achieved MMT grade 4, four MMT grade 3, and two MMT grade 2 at the final examination. Improvement in elbow flexion power to MMT grade 3 was observed at a mean of 15.9 ± 5.9 POM. In five patients, in whom we measured muscle activity using the EMG system, compared to MVC, mean amplitude of biceps with/without HAL during elbow flexion were 75.1 ± 22.8% and 60.3 ± 16.8%, respectively (Fig. 2, 3). The biceps with 5 seconds of elbow flexion and conventional biofeedback training were 75.8 ± 39.5%, 64.2 ± 20.4%, respectively. The biceps mean amplitude measurements with HAL in both methods were significantly higher than without HAL.

DISCUSSION: The upper limb HAL can assist real-time voluntary elbow motion by detecting muscle action potentials on the surface of wearer's arm skin. Therefore, HAL enables elbow flexion training even in patients with insufficient strength to flex their elbow (MMT grade 1). We believe that training with the upper limb HAL following ICN-MCN transfer for BPIs has the potential to be a novel biofeedback therapy using robotic technology. In this study, the activation of the biceps during elbow flexion with HAL (ability to flex, afferent contraction) was higher than that without HAL (unable to flex, isometric contraction), with a significant difference. The activation of biceps during elbow flexion for 5 seconds with HAL (afferent contraction) was also higher than conventional biofeedback training (isometric contraction) with a significant difference. This suggests that the biofeedback training with HAL is electromyographically of higher quality and more effective than conventional biofeedback training. We believe that the real elbow flexion in the early stage after re-innervation might evoke plasticity of the CNS, enabling easier synchronization between the brain motor center and elbow motion. Our results suggest that biofeedback training with upper limb HAL is a potentially electromyographically effective robotic training method after BPI. However, future studies should include a higher number of patients with BPI and elbow flexor reconstruction, as well as randomized controlled trials that compare the effectiveness of other conventional biofeedback training.

SIGNIFICANCE/CLINICAL RELEVANCE: The upper limb HAL (Hybrid Assistive Limb) is a new robotic device that provides a potential robotic biofeedback technique for clinical musculoskeletal rehabilitation in patients with brachial plexus injury.

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IMAGES:

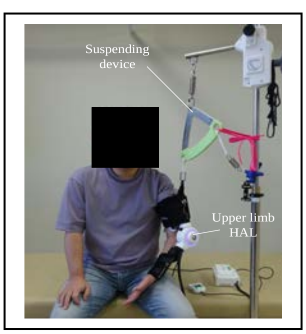

Fig 1

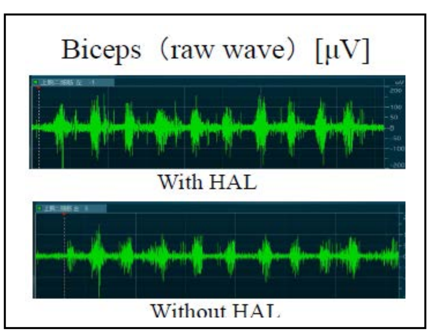

Fig 2

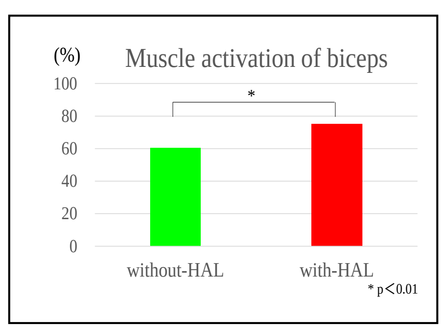

Fig 3