Evaluation of Grasping Power by means of Functional Electrical Stimulation in a Patient with C6 Complete Tetraplegia

Abstract—Grasping power (GP) by means of functional electrical stimulation (FES) was measured in a patient with C6 complete tetraplegia. This was compared with GP by means of the dynamic tenodesis effect, the flexor hinge splint and the GP of normal female.

Palmar grasp strength by means of FES was approximately 16% of the control group and 2.4 times greater than the flexor hinge splint. Lateral grasp strength by FES was approximately 13% of the control group.

Our results suggest that FES is more effective than the flexor hinge splint in increasing the GP of tetraplegic patients, and that stronger and a stable GP, which is not affected by wrist position, makes FES practical for improving activities of daily living (ADL).

Index Terms—Functional electrical stimulation, tetraplegia, grasping power.

INTRODUCTION

FES enables the patients with high spinal cord injury to reconstruct grasp movements such as the palmar and lateral grasps of the upper extremities, and therefore it is useful for improving ADL. However, there are few reports on how GP can be measured by FES, as well as on the relation between GP and the practical uses of FES.

PURPOSE

The purpose of this investigation is to evaluate the GP with and without FES, and to consider the relation between GP and the practical uses of FES in a tetraplegic patient.

SUBJECTS

A 20-year-old female patient with C6 complete tetraplegia (Frenkel A, Zancolli 2B-2) was evaluated. For comparing GP 31 normal, female students, aged 19 to 24 (X=21) were controlled.

The patient was injured in a traffic accident in June 1995. She was admitted our hospital for the purpose of reconstructing upper-extremity function by FES on November 1996. Before reconstruction, MMT of her upper extremities was showed only T in elbow extension and F in forearm pronation. Wrist extension was relatively better at G. Wrist flexion, and finger flexion and extension, were both Z (table 1). There was little joint contracture and spasticity.

Because her palmar grasp by the dynamic tenodesis effect was not practical, devices were necessary for eating, brushing teeth, grooming, and writing.

Percutaneous intramuscular electrodes (SES114, Nipponseisen Co. Ltd., Japan) were implanted on December 6, 1997, 18 months after the injury. In order to reconstruct finger extension motion, implanted regions were the deep branch of the radial nerve, the extensor digitorum, the extensor indicis, the extensor pollicis longus, the abductor pollicis brevis and the opponens pollicis. In order to reconstruct finger flexion motion, implanted regions were the flexor digitorum superficialis, the flexor digitorum profundus, the flexor pollicis longus, the adductor pollicis and the first dorsal interosseus.

Therapeutic electrical stimulation was started 13 days after the implantation operation. Palmar and lateral grasps were reconstructed at the right upper extremity by means of a portable multi-channel FES system (FESMATE CE1230,

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<th>Table 1: MMT before reconstruction</th>
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NEC Medical Systems, Japan) 8 weeks postoperation (Fig 1). Following FES reconstruction, the patient was able to perform many actions using the palmar and lateral grasps; FES enabled her to drink canned juice, eat with a spoon, write with a pen, brush her hair, and turn a tap on and off without using devices.

METHODS

GP of palmar grasps were measured in the right upper extremity of both the control group and the patient using JAMAR Hydraulic Hand Dynamometer (PC-5030J1, Preston, U. S. A); lateral grasp strength was measured using a Hand Finger Dynamometer Set (SPR-6500, SAKAI Medical Co. Ltd., Japan). In the patient, palmar grasps were performed by the dynamic tenodesis effect, the flexor hinge splint, and FES. Lateral grasp was performed with FES only.

Both the control group and our patient were made to sit deep down in a wheelchair for the measurement. Further, the right upper extremity was hung down beside the hand rim naturally, with the elbow joint extended, for measuring palmar grasps (Fig 2 A); 1/3 of the distal forearm was placed on the desk lightly to measure the lateral grasp (Fig 2 B). Grip amplitude of the hand dynamometer was 2 inches.

A maximum of GP values, by measuring 3 times, was adopted for the control group; mean values were calculated.

In the patient, GP values were measured in the same manner 3 times during one week; mean values were also calculated.

RESULTS

GP of palmar and lateral grasps were 33.2 +/- 3.1 kg and 8.3 +/- 1.0 kg, respectively, in the control group. In the patient, grasping power by means of the dynamic tenodesis effect was unmeasurable. Palmar grasp strength with flexor hinge splint was 2.2 +/- 0.3 kg. With FES, it was 5.3 +/- 1.5 kg, approximately 16% of the control group; and 2.4 times greater than the flexor hinge splint. Lateral grasp strength with FES was 1.1 +/- 0.2 kg, approximately 13% of the control group (Fig 3).

DISCUSSION

Hatta et al. [1] explains that because finger muscle forces and motor hand skills show different aspects of upper extremity function, we should measure both force and skill when evaluating upper extremity functions. Accordingly, we should also measure the finger muscle strength of grasping and pinching when evaluating upper extremity function reconstructed by means of FES.

Peckham et al. [2] has suggested that generally one kilogram is the minimal acceptable strength for the pinch grasp. FES reconstruction made it possible for our patient to perform many actions using palmar and lateral grasps in her daily life. Brushing her hair and turning a tap on and off were the most practical skills that FES allowed her to do. Both of these tasks require a strong and stable GP not affected by wrist position. Although the grasping power in our patient is less than that of the normal group, it is better than the standard established by Peckham. As the diagram indicates, stable prehension was maintained even during

![Fig 3. GP of palmar and lateral grasps in the control group and the patient with dynamic tenodesis effect, flexor hinge splint, FES; □ palmar grasp; ★ lateral grasp.](image-url)
wrist joint flexion (fig 4). It is likely that advantages make FES practical for ADL, and better than the flexor hinge splint.

CONCLUSION

Our results suggest that FES is more effective than the flexor hinge splint in increasing the GP of tetraplegic patients, and that a stronger and stable GP which is not affected by wrist position, make FES practical for improving ADL.

References