Tenodesis grip augmented by EMG controlled FES

Thorsen R 1, Occhi E 2, Boccardi S 1, Ferrarin M 1

1 Bioengineering Centre Fdg, Found. Don Carlo Gnocchi Onlus Irces, Milano, Italy
2 Spinal Unit Azienda Ospedaliera E. Morelli Sondalo (So), Italy

Email: rthorsen@cbi.dongnocchi.it

Abstract

A method for enhancing the grasp has been tested on selected C6/C7 tetraplegic subjects. Myoelectric activity detected from the wrist extensor muscles was used to proportionally control electrical stimulation delivered to the finger flexors using a specially devised system (MeCFES - Myoelectrically Controlled Functional Electrical Stimulator). Functional grasping (lateral pinch, palmar grasp and tripod grip) has been tested with and without the MeCFES. An immediately improved functionality of the hand was found when using the MeCFES and no specific training of the subjects was required. The proposed approach has proved a feasible way to enhance hand functionality in selected tetraplegic subjects.

1 Introduction

Recovery of hand function is one of the main objectives in rehabilitation of people with C6/7 tetraplegia (group G2-G5 according to the international classification for surgery of the hand in tetraplegia [1]).

When the finger flexors are paralysed the tenodesis effect can be promoted to obtain a lateral grasp (key grip) and/or palmar grasp due to the muscle/tendon tension of the finger flexors produced by wrist extension.

Surgery [2] may in some cases enhance the tenodesis effect, but some patients may want/need other alternatives.

If the finger flexors are innervated functional electrical stimulation (FES) can be used to generate the necessary muscle contraction.

The FES can be controlled by shoulder movements [3][4] or pushbuttons [5] but it is desirable to use synergistic movements such as volitional wrist extension [6,7]. Myoelectric control has already proved useful in prosthesis [8,9] and for letting the wrist extension control stimulation of itself [10] or flexor pollicis brevis and adductor pollicis [11] to obtain a functional key grip in C5 tetraplegic persons having sufficient wrist extension.

With the aim of expanding the possibilities to improve tetraplegic hand function, obtaining a functional grasp, we have tested the MeCFES method in a new configuration; myoelectric signals from the wrist extensors (ECR: Extensor Carpi Radialis Longus/Brevis) are used to control FES of the FPL and/or the finger flexors (FDS: Flexor Digitorum Superficialis and possibly the FDP)

2 Methods

The MeCFES system consists of amplifier, signal processor and stimulator. Myoelectric signals are processed with a comb filter and a blanking filter. Stimulation is biphasic (300µs double pulse with 300µs interphase-interval at 16.7pps) with amplitude computed as a piecewise linear (PWL) function of the low pass filtered (first order 1Hz filter) RMS value of the filtered recorded signal [10,12].

EMG electrodes were placed over the muscle belly of ECR proximal to the radiohumeral joint. Stimulation (Pals, Axelgaard, USA) was applied to motor points of the FDS and FPL medially on the anterior part of the forearm.

We have recruited 9 adult tetraplegics with tetraparesis in a stable phase (C6-C7 Asia classification; Group 2-3-4-5, int. Class. Surg. in tetraplegia) with active voluntary wrist extension. Positive response of FPL and FDL to electrical stimulation. No contraindications for FES. All subjects had skin sensation and could feel the stimulation.

Of 9 patients tested 5 responded sufficiently well to stimulation with sufficient level of myoelectric activity in ECR (table 1.)

To evaluate the effectiveness of grasping with and without the MeCFES, the following tests were chosen: A) using the key grip (lateral pinch) to pick up a VHS cassette, moving over
an obstacle (a bottle) and releasing it; B) using the palmar grasp for grasping a half litre (h:20cm, Ø:6cm) bottle of mineral water and drinking it; C) using the tripod grip to take a thick pen (Ø2cm) and writing.

<table>
<thead>
<tr>
<th>Subj./Sex</th>
<th>Level/Class</th>
<th>Post Injury</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>A/M C6-C7</td>
<td>DX:G4</td>
<td>2 y</td>
<td>45</td>
</tr>
<tr>
<td>B/M C6-C7</td>
<td>DX:G4</td>
<td>5 y</td>
<td>26</td>
</tr>
<tr>
<td>C/M C6</td>
<td>DX:G4</td>
<td>7 y</td>
<td>30</td>
</tr>
<tr>
<td>D/M C6</td>
<td>SX:G4</td>
<td>3 y</td>
<td>24</td>
</tr>
<tr>
<td>E/M C7</td>
<td>DX:G4</td>
<td>3 y</td>
<td>42</td>
</tr>
</tbody>
</table>

**Table 1:** List of subjects. DX: = Right hand. SX: = Left hand. In two patients both hands were tested, whereas in the other seven only one hand was suitable for inclusion.

The test was carried out before and after application of the system and recorded on videotape for later evaluation of the hand function.

For each test a score was given from zero to four. Points were given according to how well the subject could perform the task, one point each for: taking, lifting, manipulate and placing the object. The task should be performed with intended grasp and hand:

0: Not able to perform any part of the task.
1: Insufficient force to lift object.
2: Grasping and lifting.
3: Grasping, lifting and carrying out the task.
4: Completion and carefully replacing object

### 3 Results

All five subjects understood immediately how to operate the system and needed no training.

Subject A had similar capacity of right and left hand and could hold around the cassette and the bottle but with insufficient force to lift them, thus scoring 1 for both hands. He could not fold the fingers around the pen, thus scoring 0.

Assisted by the MeCFES, he completed all tests with each hand (4 pts.) (see Figure 1). With right hand he could take the pen and write.

**Figure 1:** Subject A picking up, moving and releasing a video cassette (test one).

We splinted the index IP joint of subject B with a piece of tape to stiffen it at 10° to compensate for excessive flexion. Without the MeCFES, the object tended to slip from the key grip when lifting and the object was dropped rather than put down (3pts). Holding the bottle was barely possible and he could not bring it to his mouth for drinking (2 pts). Taking the pen was impossible (0pts). With the MeCFES his keygrip became firmer and he could easily perform the first two tasks (4pts) as well as write (4pts).

Subject C was able to perform the first task but using alternative grasp (1pt. demonstrated key grip but using alternative grip when lifting). Lifting and handling the bottle was done with support of left hand (1pt.). With the system he gained a firmer key grip allowing to manipulate the cassette (4* pts) and to bring the bottle to the mouth with one hand with difficulty (4* pts.). (*Left hand was used briefly in both cases to push the object further into the hand, but probably more as a result of habit of using both hands than out of necessity). The subject declined to do the writing test.

Right hand of subject D had very good functionality and only left hand was tested. Key grip was possible but with insufficient force to lift it off the table (1 pts.) but grasping and drinking from the bottle was possible (4pts). With MeCFES the first test was performed without difficulty (4pts) and the bottle was handled with a firmer grip (4pts). The writing task was omitted since it was not the dominant hand.

Subject E had good right hand and could perform the tasks with little difficulty though rather balancing the cassette in the hand than grasping (2pts) and with less than sufficient strength to hold the bottle to his mouth (2 pts.).

With the MeCFES, both tasks were completed though with difficulty (4pts each). As for the writing task which he completed (4 pts.) with and without the MeCFES he reported that the stimulation was more hindrance than help.
Table 2: List of the six tested hands of five subjects. For each column the score on the left is without the MeCFES; and the score on the right side is with use of MeCFES (Note that subject A was tested bilaterally). The asterisk indicates where the subject has used a short corrective action with the other hand.

<table>
<thead>
<tr>
<th>Subj./Hand</th>
<th>Key grip</th>
<th>Volar grip</th>
<th>Pinch grip</th>
</tr>
</thead>
<tbody>
<tr>
<td>A/DX</td>
<td>1</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>A/SX</td>
<td>1</td>
<td>4</td>
<td>NA</td>
</tr>
<tr>
<td>B/DX</td>
<td>3</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>C/DX</td>
<td>1</td>
<td>4*</td>
<td>NA</td>
</tr>
<tr>
<td>D/SX</td>
<td>1</td>
<td>4</td>
<td>NA</td>
</tr>
<tr>
<td>E/DX</td>
<td>2</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>

4 Discussion and Conclusions

Restoring hand function in tetraplegic patients in the group G2-G3-G4-G5 of the GIENS classification, can be possible using myoelectrically controlled functional electrical stimulation with non-invasive surfaces electrodes. We have seen immediate functional results in 5 of 9 patients tested (5/11 hands considered) of which one patient would undoubtedly benefit in activities of daily life with both mono and bilateral system.

These findings justify further development of the system so that it can be proposed to selected patients as a possible alternative to existing treatments or aids. In future research we aim to let patients try the system on a daily basis.

References


[8] Motion Control, Inc., 2401 South 1070 West, Suite B, Salt Lake City, Utah, 84119-1555, USA


Acknowledgements

Thanks to the participants of this study, to the EU NeuralPro as part of the"Human Potentials Project” (contract HPRN-CT-2000-00030) and to the Italian Ministry of Health (Ricerca Corrente IRCCS) for sponsoring this study.