Upper Limb Outcomes in Stroke Subjects following Neuroprosthetic Functional Electrical Therapy versus a Graded Arm Exercise Program

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Abstract

Purpose: A study was undertaken to assess the utility of neuroprosthetic functional electrical therapy (NPFET) to enhance arm function in chronic stroke subjects. Method: Randomized controlled study in which subjects were allocated to a program of NPFET or a program of customized arm exercises known as GRASP (Graded Repetitive Arm Supplementary Program). The NPFET group underwent an average of 25 sessions of treatment over a 10 week period. NPFET was provided by a physiotherapist in a rehabilitation hospital setting. The control group received 1:1 instruction on the GRASP exercises, were encouraged to practise exercises at home on a daily basis for 3 months, keep a daily exercise activity log and were followed up by phone interviews to monitor compliance. Only subjects with Chedoke McMaster Stage of Motor Recovery (CMSMR) 1, 2 and 3 (indicating no functional motor recovery in the arm) were admitted to the study. Average time since stroke onset: 5 years. Average age of subjects: 57 years. Outcome measures: Fugl-Meyer Assessment (FMA), Ashworth Assessment and Motor Activity Log (MAL). [It was not possible to apply other planned testing measures: Action Research Arm Test (ARAT), Box and Block Test (BBT) and Rehabilitation Engineering Laboratory Hand Function Test (REL Test), due to the severe motor impairment of the subjects]. Subject assessments were completed at baseline, on completion of intervention and 2-3 months post intervention. Results: By study completion 10 subjects will have received NPFET training and 7, the GRASP protocol. Post intervention assessments have yet to be completed to ascertain long term outcomes. To date no significant change in functional use of the arm observed. Conclusion: In this group of severe chronic stroke CMSMR 1, 2 & 3 subjects, NPFET did not produce functional arm change in spite of an intensive upper limb stimulation program. All subjects were significantly constrained by loss of shoulder rotator cuff muscles as well as middle/anterior deltoid muscles to abduct and control the arm in space. This aspect of motor impairment proved problematic, limiting the usefulness of the NPFET for forward reaching with the arm.

1 Introduction

1.1 Background

Improving functional use of the upper extremity in stroke is one of the more challenging aspects of stroke rehabilitation. In Canada, with an incidence of approximately 40,000 new strokes each year it is estimated that up to 30% or approximately 13,000 stroke survivors will not regain even minimal functional use of the arm on the side of the body affected by the stroke. As the survival period post stroke can extend to 10+ years survivors face a significant period of disability and dependency. Severity of arm paralysis is commonly denoted by a 7 point scale known as the Chedoke McMaster stages of Motor Recovery (CMSMR) scale. Patients assessed to have a Stage 1, 2 or 3 CMSMR three weeks post stroke onset are found to have poor functional outcomes in the affected arm and do not recover sufficient motor activity for activities of daily living. This segment of the stroke population presents a rehabilitation challenge as there is little intervention that can be offered to improve limb function especially as stroke chronicity increases. Compensatory techniques and adaptation to one-handed techniques in ADL are frequently the most common approach.
NPFET involves the application of multi-channel, programmed stimulation to proximal and distal arm muscles to move the whole arm in a functional pattern. Stimulation channels are pre-programmed to produce unidirectional or reciprocal motion. Stimulation applied simultaneously to the shoulder, elbow, wrist and hand muscles can be tailored to individual motor presentations to generate movement and muscle contraction unachievable by the subject’s effort alone. As with other stimulation approaches NPFET also assists with joint range of motion, force of muscle contraction, temporary relaxation of spastic muscles and practice of upper limb bi-manual activities.

NPFET applied 3 weeks post stroke has demonstrated superior outcomes in motor improvement when compared to conventional exercise programs. In another recent study using the 4 channel Compex Motion Stimulator in which upper limb muscles were stimulated to practise reaching & grasping with the hemiplegic arm, improvement was seen in a number of outcome measures including Fugl-Meyer, Barthel Index and Functional Independence Measure.

In other acute and chronic stroke studies FES interventions have concentrated on stimulation of the fore-arm muscles in the presence of voluntary wrist extension or where there is a higher average initial pretreatment Fugl-Myer score indicating some proximal arm control. In this study only subjects with low (<20/60) Fugl-Myer scores exhibiting severe shoulder and elbow impairment as well as synergistic spastic activity at the wrist and fingers and no voluntary wrist extension were recruited.

### 2 Method

#### 2.1 Subjects

- 17 subjects (9 males, 8 females); Age range 31-77 years; Time since onset: 1-13 years; Affected side: L: 11 R: 6; 4/6 right side subjects were moderately aphasic.
- 10 subjects ambulated for mobility, 5 were partially (independently) ambulatory, 2 were unable to ambulate except with major assist for short distances.
- All, (except 2 subjects in a care facility), lived in their own homes.
- All subjects demonstrated CMSMR stage 1, 2 or 3 (fig 1) with a distribution of 4 subjects at stage 1, 5 at stage 2 and 7 stage 3.
- Baseline Fugl-Myer Scores 4 to 20/60. 12 subjects (70%) < 15/60
- Modified Ashworth Scale: 1+ to 3.

<table>
<thead>
<tr>
<th>Stage</th>
<th>Description</th>
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<tbody>
<tr>
<td>1</td>
<td>Flaccid paralysis is present. Phasic stretch reflexes are absent or hypotonic. Active movement cannot be elicited reflexly w/ a facilitatory stimulus, or voluntarily.</td>
</tr>
<tr>
<td>2</td>
<td>Spasticity is present &amp; is felt as resistance to passive movement. No voluntary movement is present but a facilitatory stimulus will elicit the limb synergies reflexly. Limb synergies consist of stereotypical flexor &amp; extensor movements.</td>
</tr>
<tr>
<td>3</td>
<td>Spasticity is marked. Synergistic movements can be elicited voluntarily But are obligatory. In most cases, the flexion synergy dominates the arm. There are strong &amp; weak components in each synergy.</td>
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#### 2.1.2 NPFET Application

Using the Compex Motion Stimulator, patterns of stimulation were delivered to move the arm in flexion & extension at the shoulder & elbow combined with extension of wrist & fingers. Thumb abduction & finger flexors for grasp were stimulated in the flaccid hand. The Compex SA delivers stimulation through pre-programmed cards that deliver 1, 2, 3 or 4 channels of stimulation to produce simultaneous movement at the shoulder, elbow, wrist and hand. The objective was to facilitate functional forward reach at the shoulder to use the hand in grasp and release activities Patterns of movement are configured based on the stimulation card used, e.g. for reciprocal motion channel 1 & 2 stimulate shoulder extension & elbow flexion; channels 2 & 3, elbow & wrist extension.
2.1.3 Protocol

During stimulation subjects were encouraged to voluntarily assist the movements, especially elbow extension (out of the flexion synergy) and wrist/finger opening. Reciprocal motion at the elbow was also practised, particularly, elbow flexion & extension with shoulder ab- and adduction. In order to assess the effect of NPFET on arm posture during walking some of the ambulatory subjects practised walking with stimulation to the arm extensors (posterior deltoid, triceps & wrist extensors). With stimulation it was possible to maintain the arm in more normal extended posture and reduce the associated flexion synergy that is seen in the hemiplegic arm with the effort of walking. However there did not appear to be carry-over in improved arm posture or reduced flexion synergy following removal of stimulation.

3. Results

Preliminary findings from this study do not demonstrate motor recovery in the chronic hemiplegic arm following an intensive program of neuroprosthetic functional electrical therapy. Minor changes in Fugl Myer scores were seen in 4 treatment group subjects to date but this did not translate into improved functional of the arm. As might be expected from this finding there was no change either in the Motor Activity Log for subjects tested to date. Further 2-3 month re-evaluations will be completed on all subjects to compare baseline and post intervention findings. Complete results from both groups will be reported on conclusion of the study. All subjects tolerated NPFET very well and there were no adverse reactions to stimulation.

4. Discussion and Conclusions

This small study was undertaken in a diverse group of chronic hemiplegic subjects with low Fugl-Myer scores. None of the subjects had reaching or grasp capability in the affected arm. Although the NPFET generated contraction of shoulder muscles it was not possible to bring the arm into sufficient flexion and abduction at the shoulder to support the limb during arm activities. Also, a majority of subjects had no control of shoulder rotation, a common problem in the stroke arm. As a result it was only possible to practise exercises with table support or with the arm below shoulder level as shown in Figures 2-5. This factor highlights the very severe nature of arm impairment and difficulty in generating functional movement months after stroke when synergistic movements dominate the arm and there is loss of range of motion particularly at the shoulder. As earlier studies have shown potential in acute stroke subjects for functional arm improvement from NPFET, it appears that this is the most optimal time for this intervention. Later FES intervention, although beneficial for exercise and range of motion, does not appear to improve voluntary motor activity. The potential of FES in chronic stroke patients is also hampered by loss of shoulder rotator cuff action and atrophy of shoulder abductors making an active arm exercise program difficult. Addressing shoulder function loss early in acute stroke through intensive shoulder strengthening with FES and therapeutic exercise programs may lessen impairment at the shoulder girdle. Use of NPFET interventions for upper limb reaching and grasp may then have more utility as time since stroke progresses. Application of NPFET to improve arm posture during ambulation may also extend the potential of this intervention.

References

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