THE USE OF FUNCTIONAL ELECTRICAL STIMULATION IN A CLINICAL REHABILITATION SETTING

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INTRODUCTION

Progress in research efforts over the last number of years have lead to an understanding of most of the basic concepts on which functional electrical stimulation (FES) is based. This progress has permitted the development of methods of treating patients with FES outside of the laboratory and in the clinic setting of a Spinal Cord Injury Rehabilitation Unit. It has also led to the idea that this type of treatment can be provided for the patient who is in the immediate post-acute stage following injury, rather than limiting treatment to individuals who had an injury months or even years previously.

This concept was discussed in some detail during the presentations and discussions which took place during the last Dubrovnik meeting and forms the basis for the work described in this paper.

If we are to apply the use of FES to the patient who has had a recent spinal cord injury (SCI) a number of criteria need to be met. These can be classified as being of two types - institutional and patient.

Acknowledgment: The work on this project is partly supported by Alberta Heritage Foundation for Medical Research, Edmonton, Alberta with the Initiative Research funds for Dr Dejan Popović, who is helping us in clinical and research aspects of this project and Medical Research Council of Canada, Ottawa, Ontario

Institutional Criteria

1) There needs to be a dedicated geographically located in-patient Rehabilitation Unit specialized in the treatment of SCI patients. This, by definition, requires the availability of a full-time knowledgeable staff consisting of physicians and allied health professionals permanently employed by the Unit, which includes all the treatment disciplines needed for the successful completion of all aspects of a multi-disciplinary rehabilitation treatment program for this type of patient.
2) There should be, easily available, a laboratory knowledgeable in areas of electronic and computer design as they apply to FES, whose function it would be, not only to provide the technological linkage between the patient and the technology needed but also, the ability to service the various components of the system used to provide FES. Torque testing with the identification of fatigue when it occurs is also necessary. Miniaturization and ease of use of these components is essential if the patient is to learn how to use the equipment since he/she would be expected to be able to continue treatment at home.
3) A well qualified Orthotist, either on staff on the Unit, or easily available to provide Orthotic management is needed as a functioning member of the treatment team.
4) The availability of out-patient follow-up, not only on a regularly scheduled basis but also on a relatively emergent basis as needed.
5) The availability of a laboratory equipped to perform bone density studies should form part of the support system for this type of program.

Patient Criteria

1) The patient should demonstrate the intelligence, motivation, ability and willingness to participate in treatment with any deviation from these aptitudes being sufficient reason to preclude his/her participation from treatment by the treatment team. The decision as to suitability for treatment needs to be made on the basis of in depth evaluation of the patient by all members of the team with the final decision being made by the team in a conference setting.
2) The patient should demonstrate clinical evidence of the end of spinal shock - onset of increased tone in the paralysed limbs, beginnings of control of bowel and bladder.
3) For the purposes of our study, we selected patients who demonstrated evidence of a mid-thoracic complete lesion. This criterion could be extended to patients with upper thoracic lesions if some trunk control is present, as well as to individuals who have incomplete lesions. These latter criteria, are not those which are included in this study.
4) A contractual commitment that participation in the treatment protocol, as explained to the patient, will continue for as long as it is deemed necessary by members of the treatment team, typically one year.

MATERIALS AND METHODS

Two patients, meeting the patient criteria as described, were subjected to treatment in their post-acute period following SCI. The first patient, WF, is described in some detail in this written report, with the second patient being described verbally at the time of presentation. Both patients were chosen because they had a complete mid thoracic spinal cord injury lesion. Both were patients in the SCI Unit, University of Alberta Hospitals, prior to starting FES and for the first portion of the in-patient FES program.

Both subjects had provided informed consent and had demonstrated evidence of normal bone density in the vertebral column and in the lower extremities prior to starting FES.

WF had sustained a complete T6 spinal cord injury on September I4, I989. He had a relatively uneventful post-injury course.

After demonstrating normal bone density and no evidence of hairline fractures, he was subjected to FES beginning on February 21, 1990.

A portable stimulator was used with parameters of pulse duration of 250 μsec. and 30 Hz.

Initially, stimulation was performed on a bed with a pillow placed behind the knee, so that the knee angle was in 30 degrees of flexion. A soft resilient support was provided for the heel on both sides. The amount of initial stimulation was sufficient to provide full extension of the knee for a period of four to five seconds after which the stimulation was stopped.

Stimulation was provided to both quadriceps muscles on a daily basis with two sessions of 30 minutes each being used for stimulation.

By the time the patient was discharged from hospital on March 16, 1990, he was being stimulated for 45 minutes for each quadriceps against a resistance of 1.8 kilograms.

Peroneal nerve stimulation was started when the subject was ready to begin walking, with the use of an active electrode placed on the common peroneal nerve and the neutral electrode placed above the knee. 1.5 cm. diameter electrodes were used.

Quadriceps torque testing to the point of fatigue, was done at regular intervals. The aim was to reach a torque of at least 45 Nm. before standing was permitted.

RESULTS

One month (30 days) after the start of stimulation, a value of quadriceps torque of 55.4 Nm. was achieved. This was well above the 45 Nm. value thought to be required for safe standing.

The subject therefore was permitted to stand on that date and six days later, while being stimulated 45 minutes against a resistance of 2.3 kilograms, he achieved 30 seconds of standing five times in the parallel bars.

Stimulation was progressed to a longer period of time while maintaining the same resistance and by seven weeks he was standing for one minute and forty-five seconds, six times with stimulation.

Eight weeks after the start of FES, he started walking and the first time achieved three meters of walking which he was able to do three times. This was accomplished in parallel bars with the combined use of quadriceps stimulation and peroneal nerve stimulation.

Nine weeks after the start of FES, having achieved 1.5 hrs. of stimulation against the resistance of 2.3 kilograms, the subject was able to stand for 2.5 minutes and walk a six-meter distance which he repeated four times during one session. This was still done in the parallel bars.

Further descriptions of the progress of this individual will be provided verbally at the time of presentation.

DISCUSSION

The purpose of rehabilitation is to achieve the greatest amount of independence possible, despite the severe injuries that are frequently encountered in individuals who have had a spinal cord injury. The question that will need to be answered is whether FES can be considered as a modality of treatment during the post-acute stage of rehabilitation after clinical evidence of the end of spinal shock. If FES were to be used at that stage, it would certainly need to be employed together with all the other known modalities in spinal cord rehabilitation. One of the advantages of beginning FES early may be that the bones have not yet had a chance to reduce their density, thereby reducing the possibility of fractures when FES is begun.

In this study, we have chosen complete mid-thoracic spinal cord injured subjects so as to avoid the possibility that the results would reflect spontaneous improvement of function which could be expected in the incomplete lesion. If FES is done in patients who have a lower level of injury, particularly in the thoracolumbar junction, the possibility of a combined upper and lower motor neurone lesion being present would invalidate the results. FES provided to the cervical quadriplegic patient may not be appropriate in our present state of knowledge, given the additional stimulation that would be required to keep the patient upright.

This method of choosing complete mid thoracic lesions provides us with the opportunity of studying all the parameters necessary to achieve functional walking, studied in such a way as to be able to apply these parameters to other spinal cord injured patients. While the number of individuals that we have chosen thus far is insufficient to make a statement regarding the feasibility of the use of FES in the post-acute stage of rehabilitation, the results obtained both in terms of the improvement of muscle bulk and function and the absence of any major complications, may indicate that this approach may be worthwhile. Further study is needed in this population of patients and this type of study is presently ongoing. Because of the low percentage of patients who present with complete mid thoracic spinal injuries, it is expected that this study will not be completed for many months.

CONCLUSION

A preliminary report describing the use of FES in the immediate post-acute state following SCI has been presented. The possibilities of this type of intervention being included in the post-accident rehabilitation process, the parameters of stimulation and progress have been discussed. Further study is needed to properly validate this treatment approach.

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