# EMG Feedback Treatment of Upper Limb in Hemiplegic Stroke Patients: A Pilot Study

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ABSTRACT. Basmajian JV, Gowland C, Brandstater ME, Swanson L, Trotter J: EMG feedback treatment of upper limb in hemiplegic stroke patients: pilot study. Arch Phys Med Rehabil 63:613-616, 1982.

• Poor prognosis for upper limb recovery of stroke survivors has not changed in at least 28 years; only 4% to 5% of patients regain arm function during or after the active rehabilitation phase. This pilot study included 37 patients randomly assigned to either an integrated behavioral-physical therapy treatment program including electromyographic feedback (experimental group) or a standard exercise physical therapy program of like duration and intensity (control group). Both groups showed clinically significant improvements that exceeded previously reported experience. The experimental technique appears to be more effective when upper limb involvement is not severe in a late case, or when treatment is started early (within 3 months poststroke) in a severe case. The rehabilitation community should quickly investigate the improved prospects of restoring a greater number of useful upper limbs in this often neglected group of hemiplegic patients.

Results of rehabilitation therapy for upper limb dysfunction in hemiplegic patients are acknowledged to be discouraging both for patients and the rehabilitation team. In a previous report Gowland[5] summarized findings for 229 patients who had received intensive physical therapy for upper limb problems, but showed that only 5% regained functional use of their arm and hand during rehabilitation. This was in spite of very intensive efforts on an inpatient basis. These discouraging results, which agree with those of others,[1,6] led to the introduction of biofeedback approaches. Immediately the question became whether this combination of behavioral methods (ie, electromyographic (EMG) feedback) with regular physical therapy would be superior. Therefore, a research study was designed to verify some evidence of clinical improvement in day-to-day results. The pilot study reported here was originally planned to include a large number of patients. But because of facility limitations and difficulties imposed by overrigorous inclusion criteria, results will be reported on 37 patients who completed the study and whose data are available for analysis.

Biofeedback has been used in the treatment of hemiplegia since the 1960s.[2] Most of the early reports are case studies and only a few systematically controlled experiments that purport to demonstrate the benefits of EMG biofeedback in rehabilitation of muscle function have been reported.[2] Flaws in methodology limit the validity of conclusions which have been generally very favorable.

Annual incidence of stroke in North America ranges from a reported 1.8 to 2.73/1000 individuals with a survival rate of 2 in 3 patients.[8] Thus, approximately a half million survive annually and some 3 out of 4 survivors have either temporary or permanent loss of upper limb function. Studies[5] reveal that 71% showed no recovery, 12% moved from stage I to stage II on the Brunnstrom scale[4] (rather insignificant in activities of daily living), and 17% showed improvement beyond stage II.

Against this discouraging background, it is essential that improved techniques be developed for treatment of the hemiplegic upper limb if possible. Such study ideally should be double blind and have some form of crossover with blinded objective rating of patient change. However, to do EMG feedback on a truly double-blind basis is almost impossible and a crossover might be possible in at least 1 direction only; that is, the patient treated without experimental technique is later treated with it following regular treatment methodology. In this pilot study a blind separate investigator evaluated the patents with no knowledge of EMG biofeedback techniques or which patients received which type of treatment. We believe that the results are a fair presentation of the effectiveness of both the experimental and control therapies.

## METHODS

### Patients

Patients were recruited on the basis of having had a stroke 2 to 5 months before inclusion in the study; they were referred by family physicians. Patients had to show a residual defect in upper limb function and to formally consent to collaborate in the project. They were first tested for their level of upper limb function using the Brunnstrom Staging of Motor Recovery.[4] They were then assigned randomly (from a table of random numbers) to 1 of 2 treatment groups. Stratification was used to ensure homogeneous groups according to the following criteria: (1) Brunnstrom's stages of recovery, stages 3-4 versus 5-6; (2) degree of motor involvement only versus motor plus moderate sensory and/or perceptual involvement; (3) length of time poststroke, 2 and 3 months versus 4 and 5 months. Pretest patient characteristics are summarized in table 1.

### Classifications

Loss of function was measured on the basis of the Upper Extremity Function Test (UEFT). Patients were classified as "severe" (less than 20 points) or "mild" (20 points or more). Typically, patients who scored less than 20 points on the UEFT could do no more than lift the hemiplegic hand off

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Table 1: Pretest Patient Characteristics ($n$=37)

| Characteristic | Biofeedback | Control |
|---|---|---|
| Age | 65(40-79*) | 62(48-74) |
| Time poststroke (months) | 3.5(2-6) | 2.8(2-5.5) |
| Motor control (UEFT) | 31(0-88) | 39(0-90) |
| Sensation (OSOT) | 12(1-16) | 12(0-16) |
| Perception (OSOT) | 84(59-99) | 85(50-100) |
| Mental status (NDB) | 11(2-27) | 7(1-27) |

*Mean score and range.

their lap, touch the hand to their lips, and/or use the hand to grasp medium-sized objects (2.5, 5, and 7.5cm diameter). These activities required neither coordinated performance nor manipulation of small objects with thumb and individual fingers. The following are examples of activities that are functionally possible for a patient to accomplish with the involved limb, either as an assistant or as the main executor of an act. These activities show functional advances which occur with a 10-point change over a scale from 0 to 100. For example, at 20 points a patient can stabilize an object (such as a steering wheel) without shoulder or elbow support, thus permitting him to drive. By 30 points a patient is able to pick up and carry medium-weight objects in the involved hand while the uninvolved arm is occupied with a cane. This allows objects to be carried from place to place. Progressing from 0 to 100 on the UEFT will result in the following examples of functional advantage to the patient:

0 – no function
10 – holding a book for reading
20 – driving
30 – carrying objects from place to place
40 – dressing
50 – feeding
60 – shaving/make-up
70 – hand crafts
80 – fine crafts (needle work, gardening, carpentry)
90 – card playing
100 – letter writing/typing

A gain of 10 points or more is clearly a worthwhile clinical improvement.

The UEFT evaluates: grasp (measured by wooden blocks of increasing size and mass); grip (measured by a small and large iron pipe); lateral prehension (measured by a slate); pinch (evaluated by patient's use of thumb and index, middle, ring, or small finger to pick up different sizes of weighted spheres and objects); placing (evaluated when patients place washer over nail, or put clothes iron on shelf); and supination and pronation (evaluated as patients pour to and from glass and place hand on head, behind head, or to mouth). Pre and post-treatment assessment was carried out by an independent specially trained observer, who was deliberately kept unaware of all patient treatment programs. Additional testing included the Minnesota rate of manipulation test,[9] the nine hole peg test,[7] and grip and pinch. For sensation and perception, the Ontario Society of Occupational Therapists (OSOT) test was employed; for aphasia, the Reitan Indiana Aphasia Screen test[10] was given, and for mental status, the clinicians' neurological data base (NDB) was recorded.

Table 2: Distribution Resulting From Stratification Criteria ($n$=37)

| Degree of involvement | Early (2-3 months) Severe (stage 3-4) | Early (2-3 months) Mild (stage 5-6) | Late (4-5 months) Severe (stage 3-4) | Late (4-5 months) Mild (stage 5-6) |
|---|---|---|---|---|
| Motor only | 2 | 10 | 7 | 8 |
| Motor, sensory and/or perceptual | 5 | 2 | 2 | 1 |

Randomization took place within cells.

## Therapy Sessions

Therapy sessions occurred 3 times weekly, with an average of 40 minutes/session for 5 weeks. Two separate methods of therapy were employed during the session: the experimental technique of regular physical therapy as practiced in the hospital with addition of EMG biofeedback, and the control therapy which is physical therapy using a general neurophysiological approach.[3] It was hypothesized that as the physical therapist became more skilled, learning could occur which could progressively improve results and possibly distort results. However, later analysis showed this was not a factor.

EMG equipment used for the experimental group was the Cyborg BL 900 and Q 880 system[a] with outputs to an oscilloscope when needed and a digital recording device.

## Analysis

Statistical analysis with assistance of the Department of Biostatistics and Epidemiology, which had been involved throughout the study, included at first a 4-way analysis of variance to evaluate (1) biofeedback versus control group, (2) degree of motor recovery, (3) time poststroke relative to (4) upper extremity function testing which served as a dependent variable. Secondary study objectives were to identify certain patient subgroups who would benefit more from this type of therapy and to evaluate the effect of time poststroke on outcome (degree of motor control, sensation, perception, mental status, time poststroke, and age).

Because of differences in pretest score means, analysis of covariance was performed with adjustment of pretest means.

# RESULTS

Stratification results of the 37 patients are shown in table 2. Four-way analysis of variance for evaluating UEFT results relative to difference between the 2 groups, the stage of motor recovery, the extent of the involvement and time poststroke all showed no significant difference between experimental and control groups. However, significant improvement had taken place from pre to posttreatment in the total study population.

In evaluating the effects of variables on outcome, 2 features were found to significantly correlate with outcome. These were the time poststroke and the degree of motor involvement. Patients who were treated earlier (2 to 3 months poststroke) averaged 21 points of improvement on the UEFT while those who were treated later (4 to 5 months poststroke), averaged only 7-points improvement from pre to posttest scores.

Patients with more motor control (20 points or more on the UEFT) averaged 20-points improvement, while those

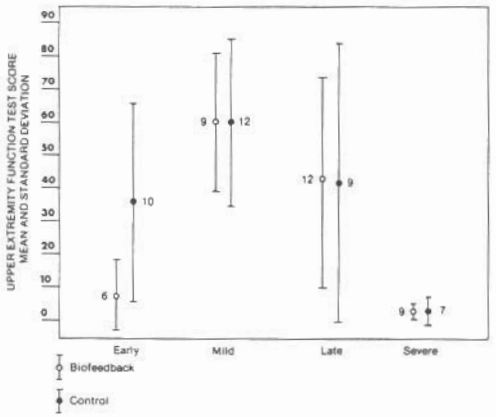


Fig 1—Pretest arm function scores of biofeedback and control groups.

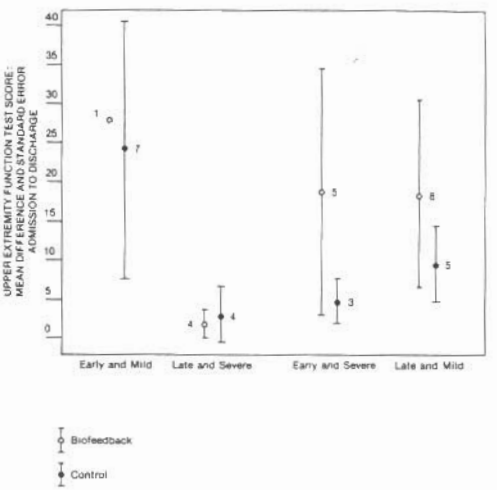


Fig 2—Effectiveness of physical therapy with and without biofeedback, comparing early-mild with late-severe cases, and early-severe with late-mild cases.

with less motor recovery (less than 20 points) gained only 6 points more function from admission to discharge. Bearing in mind that time poststroke and degree of motor involvement significantly affect outcome, it appears that this randomization and stratification process resulted in the control group being more favorably disposed to recovery than was the biofeedback group. Biofeedback group patients averaged 3.5 months poststroke, while those in the control group were 2.8 months. Also, biofeedback group patients had less arm function (31 versus 39 points on the UEFT) than those in the control group.

Early patients in the control group had substantially more arm function (35 versus 7 points on the average) than did their biofeedback group counterparts (fig 1). The other 3 groupings showed biofeedback and control patients to be comparable. Because patients who had mild disability and who were early had more favorable prognosis, 4 additional patient subgroups were investigated: (1) early and mild, (2) late and severe, (3) early and severe, and (4) late and mild (fig 2). Unfortunately, there was not a homogeneous group in comparing early and mild. Only 1 patient had fallen into the biofeedback group. All patients who were early and mild showed substantial improvement in arm function averaging about 25-points gain from pretest to posttest scores. This equates with excellent clinical improvement well above the required 10 points. On the other hand, those patients who were late and severe, averaged less than a 5-point gain and none of them benefited clinically from either treatment approach. Chance had also placed more patients with greater pretest arm function in the control group, making comparisons impossible.

Because of the difference in pretest score means, an analysis of covariance with adjustment of pretest means was performed. Again, significant differences in the total study population were not shown, but findings relative to those patients who were early and severe and late and mild were found interesting (fig 2). Although this analysis was hampered by a very small sample of patients (13 in the biofeedback and 8 in the control group), the biofeedback group improved 10.75 points more on the UEFT, thus showing a clinically superior outcome.

Using a one-tailed $t$ test, $t$ was equal to 2.07 with 19° of freedom. This resulted in $p<0.05$, demonstrating statistical significance. Using analysis of covariance to control for pretest means an $f$ value = 3.47 with 1/18° of freedom and $p<0.08$ was determined. This was not quite significant. Although clinical difference was attained, a statistically significant difference was not proven, even in early and severe and late and mild subgroupings. The needed sample size was projected with an alpha equal to 0.05 and a beta equal to 0.1; 23 patients/group would have been required to demonstrate statistical significance.

## DISCUSSION

This pilot study provides a valuable tool for planning future efficacy studies on biofeedback therapy of upper limbs of hemiplegic patients. Obviously, sample size must be considerably larger if firm conclusions are to be drawn. However, results are provocative and bear further study. In addition, much better objective evaluative tools must be developed for the upper limb. Testing and stratification instruments require a great deal of planning. The Brunnstrom stages of recovery are useful but rather soft at the 2 ends of the scale. The UEFT proves to be a good measurement tool. In the future more measures of sensory-perceptual motor function would be added through the neuropsychology battery, as well as measures of mood, self-concept, and affect. The nine hole peg test and Minnesota rate of manipulation test (among others) have limited use-

fulness because about half the patients could not even start to do them.

Perhaps the most significant conclusion would be that studies of new therapy effectiveness for upper limb function in stroke patients should be done at the ideal stage when the surviving brain tissue has its greatest plasticity, ie, up to 4 months poststroke in patients who show greatest promise. While humanitarian considerations suggest that all patients should have biofeedback, this is unrealistic in research. Hence, future studies should be based upon the effect of new therapy on patients who have the greatest likelihood of measurable recovery. Continuing formal randomized control study will concentrate on statistically significant comparisons between patients who are early-severe and late-mild, with or without biofeedback supplement.

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a. Cyborg Corp., 55 Chapel St. Newton, MA 02158



# BOOK REVIEWS

RESPIRATORY MEDICINE AND INTENSIVE CARE FOR THE HOUSE OFFICER by *John J. Marini, MD.* Paperback. Price, $9.95. 275 pages. The Williams & Wilkins Company, 428 East Preston Street, Baltimore, MD 21202.

The preface of *Respiratory Medicine and Intensive Care for the House Officer* states that the material will be "useful to nonspecialist physicians caring for hospitalized patients with respiratory disorders" stressing principles and guidelines. However, it must be emphasized clearly that it really is intended for house officers (residents) in internal medicine, particularly, for those specializing in pulmonary medicine. Throughout the various chapters clinical skills and techniques are well described to assure a successful outcome. The text is organized in 5 sections: pulmonary physiology, clinical skills, diagnostic techniques, respiratory intensive care and clinical notes on selected topics. Each section is fairly well balanced with numerous "pearls" most suitable for training of the house officer or fellow. The book contains much of clinical utility and interest. The print is somewhat light and could be enhanced for eye ease. Some considerations although worthy of further study are fairly concise, eg interpretation of wedge pressures, optimal level of PEEP, and management of ventilatory "parameters" in mechanical support. Nevertheless, Dr. Marini's views puts into perspective many difficulties of the house officer *(Herbert Kent, MD)*

CHEST PHYSIOTHERAPY IN THE INTENSIVE CARE UNIT edited by *Colin F. Mackenzie, Nancy Ciesla, P. Cristina Imle, et al.* Paperback. Price, $23.00. 260 pages. Williams & Wilkins Company, 428 East Preston Street, Baltimore, MD 21202.

To quote from the preface "the literature is not helpful in specifying what chest physiotherapy is intended to include". This book is written by a group working in an environment of emergency medicine at the Maryland Institute for Emergency Medical Services Systems in Baltimore. Dr. MacKenzie starts with a history and review of the literature on chest physiotherapy. He then relates its clinical application to the patients seen in their institute. The physical therapists then discuss the procedures used in chest physiotherapy in their clinical cases. They also discuss some of the difficulties encountered in carrying out those procedures. Most of their patients have multiple injuries which complicate administration of chest physiotherapy. The most revealing, interesting and informative chapter is written by Dr. MacKenzie on the physiologic changes following chest physiotherapy. The most distinguishing characteristics of the book are the discussions of the indications and contradications for the use of chest physiotherapy. To the casual learner the use of chest physiotherapy may seem not cost effective, to those involved in the everyday use and to those about to initiate a program the book becomes a "must" for reading. *(Robert W. Boyle, MD)*