

# THE USE OF ELECTRICAL STIMULATION TO IMPROVE MOTOR CONTROL AND FUNCTION OF THE UPPER EXTREMITY AFTER STROKE: A SYSTEMATIC REVIEW

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## Abstract

Electrical stimulation is one of the strategies used to treat the affected arm in stroke patients. The objective of this systematic review is to summarize the available evidence on the effect of electrical stimulation in improving motor control and arm function thus far.

A systematic literature search yielded seven randomized clinical trials. The methodological scores ranged from 7 to 16 (out of 19). Different methods of stimulation were applied to heterogeneous patient groups.

All studies reported a statistically significant effect of electrical stimulation on motor control. Only two studies assessed the effect on arm function, one reports a positive effect. No relation between effect and patient characteristics, method of stimulation and/or methodological quality could be detected.

In conclusion this review suggest a positive effect of electrical stimulation on motor function. No conclusion can be drawn with respect to arm function.

## Introduction/Background

Functional impairment of the upper extremity is one of the disabling consequences of a stroke. A majority of stroke patients experience the impaired arm function as a major problem. In the quest for better therapeutic possibilities for the affected arm, many studies have been carried out to assess the effect of different interventions. Electrical stimulation is one of the strategies under study.

A meta-analysis of four RCTs supports the use of electrical stimulation to promote recovery of muscle strength after stroke [1]. But only one of the four studies evaluated the effect of stimulation of the upper extremity [2]. Since then interesting critical reviews considering the application of electrical stimulation on upper as well as lower extremity in stroke have been published [3,4,5]. The overall conclusion in these reviews is that electrical stimulation has potential benefits on both upper and lower extremity. The evidence for application of electrical stimulation to the affected arm for improvement of motor control and function remains uncertain. The available evidence thus far has not yet been evaluated in a systematic and explicit way.

The present systematic review was carried out to answer the following research question: what is the available evidence regarding the effect of electrical stimulation on motor control and functional abilities of the affected arm in stroke patients? In addition a second question was formulated: is there a relation between reported effects and patient characteristics, method of stimulation or methodological quality?

## Methods

A literature search was performed in Medline, Embase and the database of the Cochrane Collaboration up to september 2000, using the following medical subject headings: cerebrovascular disorders, hemiplegia, electrical stimulation therapy, electrical stimulation, arm and wrist joint. In addition references of relevant publications were checked.

Studies meeting the following inclusion criteria were included: 1. therapeutic electrical stimulation applied to the affected upper extremity in stroke patients, aiming at improvement of motor control or functional abilities, 2. application of stimulation with surface electrodes, 3. randomized clinical trial, 4. full-length publication in Dutch, English, German or French. Application of these criteria resulted in exclusion of studies which focussed on either electro-acupuncture or implanted electrodes. It was also decided to exclude studies evaluating the effect of electrical stimulation of the shoulder, because these studies mainly focus on pain and subluxation rather than on motor control and arm function.

Two raters assessed the methodological quality of the selected studies independently, using a list of 19 criteria [6]. In case of disagreement, consensus was reached by discussion or by consulting a third rater.

In all studies the effect of electrical stimulation, as reported by the author, was rated as positive (in favour of the electrical stimulation group), negative (in favour of the control group) or no difference. Rating was limited to relevant outcome measures with respect to motor control and functional abilities.

The results were examined to identify a possible relation between effect and patient characteristics, method of stimulation and methodological quality. A pooled analysis was considered.

## Results

Seven studies met the inclusion criteria and were included for the present review [2,7,8,9,10,11,12]. A summary of the included studies is given in tabel I. A total of 235 patients was involved. Three studies focussed on patients in the acute stage after stroke [8,9,11], two on the subacute stage [2,7] and two on the chronic stage [10,12].

The method of electrical stimulation applied varied between the studies: effects of neuromuscular electrical stimulation (NMES) [9,11], EMG-triggered stimulation [2,7,8,12], and transcutaneous stimulation [10] were described. There was considerable variation of target muscles, stimulation parameters and duration of stimulation.

In three studies [2,7,10] all patients received the same standard therapy and the experimental group received stimulation therapy additionally. In three other studies the control group received some additional therapy, other than electrical stimulation, as well [8,11,12]. One study was a placebo-controlled trial [9].

The methodological score ranged from 7 to 16 (out of 19). Most common methodological flaws were lack of concealed treatment allocation and absence of an accurate report on patient compliance, drop-out rate and/or adverse effects.

All studies assessed effect on motor control and all reported a statistically significant effect on at least one outcome measure for motor control ( $p \leq 0,05$ ). Two studies measured functional abilities [11,12], one

reported a positive effect. Follow-up measurements were performed in three studies [9,11,13], a significant difference between both groups 24 weeks after the treatmentperiod was described in one study [9].

Subgroupanalyses in 2 studies revealed a significantly better effect in less severely affected patients. Apart from this no relation between effect of stimulation and patient characteristics, method of stimulation or methodological quality could be shown.

## Discussion/Conclusions

The results of 7 RCTs were reviewed. All authors concluded that electrical stimulation has potential benefits and might be valuable in improving the affected arm after stroke. At this stage it is not possible to draw conclusions with respect to the effect on functional abilities, because it was only assessed properly in two out of the seven RCTs.

However, in all studies a statistically significant effect appeared on at least one outcome measure regarding motor control. It is not clear whether this also resulted in clinically relevant improvement.

Notwithstanding the promising result with respect to motor control, some critical comments can be made. Methodological limitations of the studies possibly resulted in a more favourable result. In three studies [2,7,10] the experimental group received extra therapy in addition to standard treatment. This contrast in therapy intensity might contribute to a more positive effect [14]. Only one study [9] applied placebo-treatment to the control group, a placebo effect might affect the results of the other studies. Moreover, lack of proper blinding can result in a favourable effect of electrical stimulation.

**Table I Characteristics, outcome and methodological score of included studies.**

author	n	stage	treatment	Relevant outcome measures	reported effect <sup>1</sup>	meth. score <sup>2</sup>
Powell, 1999	30E 30C	acute	E standard + NMES <sup>3</sup> C standard + visits PT	Isom strenght <sup>4</sup> AROM <sup>5</sup> , grip <sup>6</sup> , ARA <sup>7</sup> , 9HPT <sup>8</sup>	+ -	16
Chae, 1998	25E 21C	acute	E standard + NMES <sup>3</sup> C standard + placebo	FM <sup>9</sup>	+	13
Heckmann 1997	14E 14C	subacute	E standard + EMG-stim <sup>10</sup> C standard	AROM <sup>5</sup>	+	9
Francisco, 1998	4E 5C	acute	E standard + EMG-stim <sup>10</sup> C standard + extra therapy	FM <sup>9</sup>	+	8
Sonde, 1998	26E 18C	chronic	E standard + TENS <sup>11</sup> C standard	FM <sup>9</sup>	+	7
Bowman, 1979	15E 15C	subacute	E standard + EMG-stim <sup>10</sup> C standard	AROM <sup>5</sup> , isom strenght <sup>4</sup>	+	7
Cauraugh, 2000	7E 4C	chronic	E standard + EMG-stim <sup>10</sup> C standard + vol wrist ext <sup>12</sup>	Sust contr <sup>13</sup> , box&block FM <sup>9</sup> , MAS <sup>14</sup>	+ -	7

E=experimental group, C=control group. <sup>1</sup>scored + if  $p \leq 0.05$ . <sup>2</sup>methodological score. <sup>3</sup>neuromuscular electrical stimulation. <sup>4</sup>isometric strength. <sup>5</sup>active range of motion. <sup>6</sup>grip strength. <sup>7</sup>Action Research Arm test. <sup>8</sup>9 hole peg test. <sup>9</sup>Fugl-Meyer Motor Assessment. <sup>10</sup>EMG-triggered stimulation. <sup>11</sup>transcutaneous electrical nerve stimulation. <sup>12</sup>voluntary wrist extension. <sup>13</sup>sustained contraction. <sup>14</sup>Motor Assessment Scale.

The present review comprises seven RCTs with heterogeneity regarding patient characteristics (time since stroke, severity) and method of stimulation. Favourable effects are reported for patients in the acute as well as the chronic stage after stroke. However, it remains unclear if and how long patients can maintain the improvement gained.

Most studies selected a heterogeneous sample of patients. Interesting are the results of subgroup-analyses performed by two authors [10,11]. Both compared the results of more and less affected patients. These subgroup-analyses revealed a significant greater effect in the less severely affected group. Less severe was defined as either a Fugl-Meyer-score of at least 30 (out of 66) or residual voluntary wrist extensor strength. This leads to the hypothesis that less severely affected patients might benefit more from electrical stimulation. More research is needed to test this hypothesis.

Considering the application of stimulation, three methods could be distinguished: NMES, EMG-triggered stimulation and TENS. It is suggested that in EMG-triggered stimulation coupling biofeedback principles to electrical stimulation maximizes the effect of NMES [4]. From the present review it cannot be concluded if one method of stimulation is superior to another. In addition, there is no consensus about optimal stimulation parameters.

This implies that at this moment explicit recommendations for the application of electrical stimulation to improve motor control cannot be formulated. The positive results thus far encourage further research to clarify ambiguities considering optimal method of stimulation and stimulation parameters and to identify characteristics of patients who will benefit from stimulation. The final goal is evidence-based implementation of the application electrical stimulation to improve the affected arm in stroke patients.

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