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Enhanced physical therapy improves recovery of arm function after stroke. A randomised controlled trial

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Abstract

Previous research on stroke rehabilitation has not established whether increase in physical therapy lead to better intrinsic recovery from hemiplegia. A detailed study was carried out of recovery of arm function after acute stroke, and compares orthodox physiotherapy with an enhanced therapy regime which increased the amount of treatment as well as using behavioural methods to encourage motor learning. In a single-blind randomised trial, 132 consecutive stroke patients were assigned to orthodox or enhanced therapy groups. At six months after stroke the enhanced therapy group showed a small but statistically significant advantage in recovery of strength, range and speed of movement. This effect seemed concentrated amongst those who had a milder initial impairment. More work is needed to discover the reasons for this improved recovery, and whether further development of this therapeutic approach might offer clinically significant gains for some patients.

In Britain the typical inpatient recovering from hemiplegia due to acute stroke can expect to receive only four hours of physical therapy per week, and will do very little self-directed exercise between therapy sessions.[1 2] It is not known whether an improved therapeutic regime would lead to better recovery of voluntary control in the arm and leg. A number of large trials[3–6] have investigated the overall impact of all aspects of stroke rehabilitation. These trials have used activities of daily living (ADL) scales as the major outcome measures, and have shown in general that modest gains in ADL outcome occur if the rehabilitation effort is more intense or is better organised in specialist stroke units. ADL scales are blunt instruments[7] and do not distinguish between adaptive and intrinsic recovery.[8] The gains in function may have been due to patients learning how to compensate for motor loss, or may have reflected better recovery of motor control, or a combination of the two.

Studies concentrating on the effects of physical therapy on intrinsic motor recovery have been of variable quality.[9 10] Several properly controlled small scale studies[11–13] have compared different types of physiotherapy and have failed to detect any difference in outcome. One larger scale study by Sivenius *et al*[14] found that a 46% increase in physiotherapy during the first three months after stroke appeared to lead to better recovery of the range of active movement in the arm and leg. However, the patient groups in this study were not well matched at initial assessment which complicated statistical evaluation of results.

Previous research from this Unit[15–18] has shown that under a typical therapy regime, prognosis for recovery of arm function is particularly poor. Approximately half of all acute stroke patients starting rehabilitation will have marked impairment of function of one arm, and only about 15% of these will eventually regain useful function. A number of small scale studies have, however, suggested that recovery of the arm may be improved by various techniques including encouragement of home-based exercise,[19] avoidance of learned non-use,[20] and biofeedback therapy.[21] In this study, orthodox therapy was compared with an enhanced therapeutic regime which increased the amount of therapy for the arm and used behavioural methods to encourage active learning during treatment sessions and also through self-directed exercises.

Method

Patient selection

Consecutive patients admitted to the Frenchay Hospital or referred to the Stroke Unit for outpatient therapy, were screened for inclusion in the study. The inclusion criteria were:

1) Clinical diagnosis of unilateral acute stroke, supported by CT scan when available (54% of cases). Subarachnoid haemorrhage and brainstem strokes were excluded.

2) Inability to complete the nine hole peg test (NHPT[18]) within 18 seconds when using the affected hand, despite visual and verbal prompts to try to overcome any visual neglect.

3) Being well and alert enough to receive active therapy. Patients, 3 weeks after stroke, who still took longer than 30 seconds to complete the NHPT with the unaffected hand were judged to be too confused or drowsy to take part in the trial.

Patients who had suffered previous strokes were only included if it was clear that they had full use of the arm before the present episode.

Design

A stratified randomised controlled design was used.[22] Calculations based on the proportion of patients likely to make a good recovery under an orthodox regime[15 17] suggested that

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the study would have to include 160 patients to have a 90% chance of detecting a 20% improvement in outcome.

Patients who passed the entry criteria and were willing to participate in the study were assessed fully by the research coordinator within 21 days of their stroke (or as soon as possible thereafter when an assessment appointment could be arranged). They were then stratified according to their side of hemiplegia and performance on the Frenchay Arm Test[18] ("severe" = unable to pass any sub-test; "mild" = one or more sub-tests passed). Within these strata, patients were randomly assigned to enhanced therapy (ET) or conventional therapy (CT) groups by the research co-ordinator using pre-prepared computer generated lists which permuted blocks of two patients.

Further assessments were conducted at 1, 3 and 6 months after stroke by an external assessor who was not involved in day-to-day running of the project. Four external assessors took part throughout the course of the study and they were blind to group assignment.

Assessment Battery

The following measures were used at all assessment points. Further details of the procedures used and reasons for their use as outcome measures are given elsewhere.[16]

STRENGTH AND RANGE OF MOVEMENT

1) Extended Motricity Index (EMI). Tests from the arm section of the Motricity Index were used.[23] The rating scale for strength of pinch grip was replaced with a measure of grip strength of the hand using an electronic dynamometer, with the result being expressed as a percentage of strength of the unaffected side.[16]

2) Sub-tests of the Motor Club Assessment.[24] Three point rating scales for range of active movement in shoulder shrugging, arm lifting, wrist cocking, forearm supination and finger extension.

3) Passive Movement and Pain. Resistance to passive movement and also pain on passive movement were noted as present or absent at the shoulder, elbow and wrist.

FUNCTIONAL MOTOR SKILLS AND MANUAL DEXTERITY

1) Frenchay Arm Test.[18] Five tasks using the affected hand (stabilising a ruler, picking up a cylinder, drinking from a glass, placing a clothes peg on a dowel, combing hair) each scored as pass or fail.

2) Nine Hole Peg Test.[18] The time taken to place 9 pegs, or number of pegs placed in 50 seconds was recorded. For the first 26 patients to enter the study, three trials were attempted with the affected hand. For later patients, these trials were alternated with three trials with the unaffected hand.

BACKGROUND MEASURES

1) Sensory loss was assessed in terms of response to light touch on the back of the hand, detection of passive movement of the tip of the thumb, and the Thumb Finding Test.[25]

2) Functional independence was assessed using the Barthel ADL scale.[26] This was based on questioning nursing staff for inpatients, and questioning of the patient or a relative for outpatients.

At the one and six month assessments, there were additional brief tests for dysphasia,[27] non-verbal reasoning[28] and depression.[29]

Treatment Regimes

The CT patients were treated by the clinical physiotherapists. Those assigned to ET were immediately transferred to the project therapists for physiotherapy and occupational therapy for the arm. This was supplementary to the input from clinical occupational therapists which was the same for both groups. Most of the physiotherapy for the two groups was given in different parts of the same rehabilitation unit. Project therapists did not treat any patient in the CT group. The therapy provided is described below.

1) *Conventional therapy (CT)*

Conventional physiotherapy in the Frenchay Hospital is loosely based on the "neurophysiological" techniques. The texts by Bobath[30] and Johnstone[31] describe the major techniques used. The emphasis is on expert hands-on treatment by the therapist and patients are not routinely instructed to exercise between therapy sessions. Active movement may not be encouraged until abnormal muscle tone is well controlled.

2) *Enhanced therapy (ET)*

There were two aims. First, to give more intensive treatment for the arm, with the amount and type of therapy for the leg being similar to that in the CT group. Second, to use behavioural methods to encourage the patient and family to be active participants in arm rehabilitation,[32] and to avoid the patient being a passive recipient of expert therapy. Specific aims were to promote greater adherence to self-directed exercise programmes,[33] to combat overprotectiveness from spouses,[34] to prevent learned non-use of the affected arm,[20] and to facilitate learning of new motor skills.[35 36] An eclectic approach was taken in selection of treatment techniques, which included Bobath exercises, EMG biofeedback, micro-computer games and goal-setting. Emphasis was placed on setting the patient tasks of graded difficulty and providing objective feedback on performance. Further details of the ET regime will be given in a future paper.

Therapy in both groups was monitored throughout the course of the study. For each CT patient, one physiotherapy session per month (chosen at random) was observed by the project coordinator. Treatment given in the ET group was recorded in the treatment notes by the project therapists immediately following each session.

Results

Patients

Between August 1986 and December 1989,

Table 1 Background characteristics of patients

Therapy group	*Severe sub-group*		*Mild sub-group*	
	CT (N = 35)	*ET (N = 36)*	*CT (N = 32)*	*ET (N = 29)*
Sex				
Female	20	20	16	16
Male	15	16	16	13
Age at stroke				
median (range)	68 (50–82)	65 (32–88)	70 (35–84)	67 (46–92)
Initial assessment				
Days since stroke				
median (range)	10 (2–31)	8 (2–35)	8 (0–29)	9 (1–31)
Type/severity of stroke				
Left hemiparesis	16	14	15	14
Right hemiparesis	19	22	17	15
First stroke	28	27	26	23
Urinary incontinence	10	11	4	5
Barthel ADL				
median (range)	7 (2–19)	7 (2–20)	12 (6–20)	13 (2–20)
Number walking independently	2	1	8	10
Tests at one month only				
Frenchay Aphasia Screening test				
median (range)	15 (1–20)	12 (0–19)	18 (1–20)	16 (1–20)
Block Design (non verbal reasoning)				
median (range)	12 (0–41)	14 (0–46)	26 (0–46)	16 (0–48)
Wakefield Depression Questionnaire				
median (range)	19 (4–33)	10 (3–18)	11 (3–34)	12 (0–29)

Table 2 Initial Arm Assessment

Therapy group	*Severe sub-group*		*Mild sub-group*	
	CT (N = 35)	*ET (N = 36)*	*CT (N = 32)*	*ET (N = 29)*
Resistance to passive movement	10	9	2	5
Pain on passive movement	3	2	5	5
Definite proprioceptive loss*	16	11	7	3
Extended motricity index				
median (range)	9 (0–58)	0 (0–73)	66 (34–91)	67 (30–96)
Motor club assessment				
median (range)	1 (0–7)	0 (0–6)	8 (3–10)	9 (1–10)
Nine hole peg test				
pegs/second				
median (range)	0 (0)	0 (0)	0·05 (0–0·39)	0·08 (0–0·38)
% of unaffected hand				
median (range)	0 (0)	0 (0)	2 (0–60)	15 (0–72)
Frenchay Arm Test				
median (range)	0 (0)	0 (0)	2 (1–5)	4 (1–5)

*Defined as a score of > 1 in the thumb finding test (15% were unassessable due to dysphasia).

429 patients were screened and 137 (31%) passed the entry criteria for the study. The following results concern the 132 patients who survived beyond three months and who agreed to participate in assessments.

Tables 1 and 2 show their background characteristics and arm function at the first assessment. The groups appear to be reasonably well matched.

Table 3 Amount of physiotherapy received by patients after group assignment

Therapy group		*CT*	*ET*
Inpatient Therapy			
Duration (weeks)	median	4	7
	range	0–48	0–33
Arm therapy per week (mins)	median	53	129**
	range	0–265	8–399
Other physiotherapy per week (mins)	median	53	39
	range	0–135	0–137
Outpatient Therapy			
Duration (weeks)	median	6	11*
	range	0–45	0–50
Arm therapy per week (mins)	median	21	51**
	range	0–105	0–170
Other physiotherapy per week (mins)	median	15	8
	range	0–49	0–42

Comparison of groups, Mann Whitney U tests: *p < 0·05 one-tailed, **p < 0·01. All others p > 0·1.
The figures on type of therapy for the CT group are extrapolated from observations on a sample of therapy sessions—see text. These figures are only for time in physiotherapy. In addition, inpatients in both groups received approximately two hours of occupational therapy per week.

Therapy received

Table 3 shows the duration and frequency of physiotherapy received by the two groups. Patients in the ET group received more than double the amount of therapy for the arm. They also received more encouragement to practise between therapy sessions. Homework was set in 35% of ET sessions but in only 15% of the sample of CT sessions. An interview survey of the non-aphasic patients[37] indicated that patients in the ET group could describe more home exercises for the arm and claimed that they did them more frequently.

Recovery curves

1) Extended Motricity Index

Figure 1 shows recovery curves for the 109 patients with complete data on the EMI. A repeated measures analysis of variance[38] indicated that the ET and CT patients show a significantly different pattern of recovery (therapy type × time interaction, p = 0·006), and that this pattern does not differ significantly between mild and severe sub-groups (p > 0·2). There was no significant effect due to whether the dominant or non-dominant arm was affected.

Figure 1 suggests that the major effect of ET is in improving arm function within the first month. Recovery during that period is significantly greater for ET than CT patients (t test, p = 0·01), whereas there is no significant difference in the amount of recovery for the two groups between one and six months (p > 0·2). The other motor measures suffer from floor or ceiling effects[16] which makes it difficult to plot meaningful average recovery curves. These other measures are therefore considered in the next section on final outcome.

2) Barthel ADL

This scale suffers from ceiling effects for the mild sub-group, but is shown for comparison in figure 2. There is no apparent effect of therapy type on Barthel ADL scores (therapy × time interaction, p > 0·2).

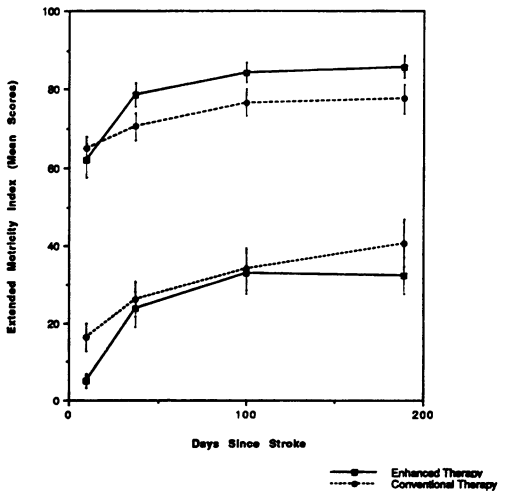

Figure 1 Recovery curves for mild and severe sub-groups on the EMI. The bars show the SEM.

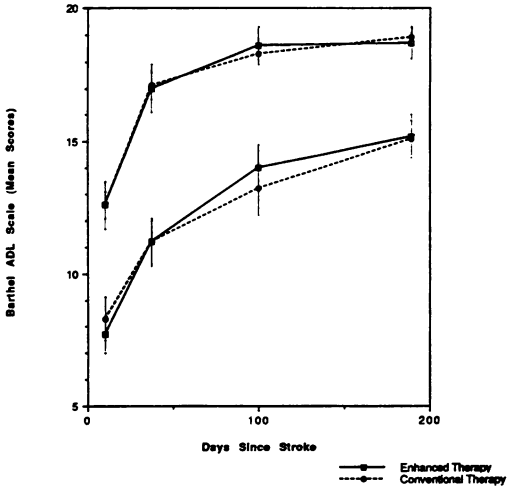

Figure 2 Recovery curves for the mild and severe sub-groups for Barthel ADL. The bars show the SEM.

Outcome at six months

Table 4 shows that the groups remain similar on background measures at six months. One patient in the ET group and one in the CT had suffered a further major stroke and been withdrawn from the study. Six patients had died, all in the CT group ($\chi^2 = 4{\cdot}2$, $p < 0{\cdot}05$), but the overall death rate (including the two patients in each group who died before the three month assessment) is not significantly different in the two groups (ET = 2/67; CT = 8/69; $\chi^2 = 2{\cdot}54$, $p > 0.05$).

Table 5 shows that at six months there was better arm function for ET than CT patients in the mild group on all measures except the Frenchay Arm Test. In the severe group there is a trend, as at the initial assessment, for CT patients to perform better. This trend reaches significance on the percentage measure of the peg test but does not approach significance on other measures where the spread of scores is very large (standard deviations on the EMI and Motor Club of 29 and 3·7 respectively, compared with 15 and 1·5 in the mild sub-group).

As expected from studies of the natural history of recovery,[8] there was an increase in the frequency of pain and resistance to passive movement compared with the initial assessment. Severe patients in the ET group fared worst in this respect with 47% developing pain compared with 26% of severe patients in the CT group. This trend does not approach statistical significance ($\chi^2 = 2{\cdot}02$, $p > 0{\cdot}2$), and may reflect the slightly more profound initial impairment of the severe-ET patients (see table 2).

Table 4 Background characteristics at six months

	Severe sub-group		*Mild sub-group*	
Therapy group	*CT*	*ET*	*CT*	*ET*
% of original sample	*(N = 30) 85%*	*(N = 34) 94%*	*(N = 30) 93%*	*(N = 27) 93%*
Days since stroke				
median	184	185	192	183
range	160–224	160–214	160–256	147–267
Barthel ADL				
median	16	17	19	20
range	7–20	2–20	13–20	7–20
Number walking independently	20	20	29	24
Frenchay Aphasia Screening Test				
median	18*	15	19	15
range	5–20	2–20	6–20	7–20
Block design (non verbal reasoning)				
median	20	20	28	24
range	6–45	0–47	4–47	6–47
Wakefield Depression Questionnaire				
median	14	9	10	7
range	2–29	1–29	2–26	0–21

Differences within the sub-groups were tested using Mann-Whitney U and χ^2 tests as appropriate. *$p < 0{\cdot}05$.

Table 5 Arm assessment at six months

	Severe sub-group		*Mild sub-group*	
Therapy group	*CT (N = 30)*	*ET (N = 34)*	*CT (N = 30)*	*ET (N = 27)*
Resistance to passive movement	18	25	9	7
Pain on passive movement	16	19	12	6
Definite proprioceptive loss[1]	6	3	5	1
Extended motricity index median (range)	41 (0–112)	28 (0–94)	70 (39–114)	87* (54–104)
Motor club assessment median (range)	5 (0–10)	2 (0–10)	9 (5–10)	10* (7–10)
Nine hole peg test pegs/second median (range)	0 (0–0·65)	0 (0–0·71)	0·35 (0–0·68)	0·44* (0·2–0·59)
% of unaffected hand median (range)	0* (0–86)	0 (0–59)	66 (0–101)	77** (29–105)
Frenchay Arm Test median (range)	1 (0–5)	0 (0–5)	5 (1–5)	5 (4–5)
number scoring maximum	6	6	21	23

Note
Differences within the sub-groups were tested using Mann-Whitney U and χ^2 tests as appropriate. *$p < 0{\cdot}05$, **$p = 0{\cdot}01$, all others $p > 0{\cdot}1$.
[1]Defined as a score of > 1 in the thumb finding test (5% were unassessable due to dysphasia).

Discussion

This study demonstrates gains in recovery due to enhanced physical therapy. These gains were apparent on tests of strength and range of movement, and on a test of manual dexterity for the more able patients. There was, however, no increase in the proportion of patients able to carry out simple untimed practical tasks with the affected arm (Frenchay Arm Test).

The ET effect was not dramatic, but the results are of clinical significance for two reasons. First, they appear to show that physical therapy can improve intrinsic motor recovery. Second, this study looked at the effects of a moderate change in therapeutic practice. Larger differences in outcome would be expected if a no-treatment control group were contrasted with the optimal rehabilitation environment which the ET regime only approximated.[1] Changes in hospital routines and more flexible therapy timetables would have allowed much more physical therapy than was received by the ET group.[39]

The improved arm function in the ET group occurred without any corresponding advantage over the CT group on measures of mood state or cognitive ability. This suggests that the improved arm function was not part of some general positive impact of ET. It was not anticipated that improved arm function alone would give rise to increased scores on the Barthel ADL scale because none of the items on this scale require normal bimanual ability. The absence of effect on the Barthel, and in particular the similarity of ET and CT groups in the proportion of patients able to walk independently, is therefore a further argument for very specific effects of the ET regime on improving arm function.

The ET regime included an increase in the amount of therapy compared with CT and also the deployment of a number of therapy and training techniques. This means that important questions over the precise locus of the treatment effect remain unanswered. The increase in amount of hands-on therapy was modest, suggesting that the self-directed exercises performed on the ward or at home may have been crucial. Evidence on adherence to exercise regimes in other disorders[33] indicates that our emphasis on patient and family involvement, and provision of feedback on progress may have been important in achieving reasonable rates of self-directed exercise.

We have no information on the neurological mechanisms which underlay the improved intrinsic motor recovery. It remains possible that improved recovery of damaged nervous tissue occurs as a direct result of more intense stimulation of the motor system[40] (see also Zihl *et al*[41] with regard to recovery of the visual system). However, we take the view that a dynamic model of neurological recovery is more appropriate. The patients in the ET regime may have progressed by learning to make best use of remaining neural pathways and learning to recruit alternative pathways to circumvent damaged areas.[42] If this was the case then the provision of tasks of graded difficulty with immediate feedback on accuracy of performance may have been an essential element in the ET regime.

Only one third of all stroke admissions were accepted for this trial. However, these were all those who were well enough to receive active rehabilitation and had persistent disability. Thus it was a representative sample of patients who would receive most therapeutic input in rehabilitation units. These results therefore have implications for current practice. The greatest treatment effect was detected in those with some initial active movement. This suggests that more attention should be given to the more able patients who at present tend to receive less therapy and be discharged early.[43] However, conclusions on the response to therapy of patients of different severity are complicated by differences in the sensitivity of measures used. The arm function measures were affected by floor effects for severe patients, with most of them scoring zero at the initial assessment. The EMI is the least affected in this way[16] and it showed no statistically significant difference in the impact of therapy for mild and severe patients. As shown in figure 1, both appeared to show an early advantage due to ET, although the severe sub-group then show a trend towards poorer final outcome than the CT-severe sub-group. More sensitive measures of function, pain and spasticity would be needed to clarify the effect of ET with severely impaired patients.

This study has demonstrated that an adequately designed physical therapy programme can lead to better recovery of arm function. Many questions have been raised and there is a clear need for further research so that physical therapy for the stroke patient can be placed on a rational foundation.

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