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Impairment-oriented training or Bobath therapy for severe arm paresis after stroke: a single-blind, multicentre randomized controlled trial

T Platz, C Eickhof, S van Kaick, U Engel, C Pinkowski Klinik Berlin, Department of Neurological Rehabilitation, Campus Benjamin Franklin, Charité – Universitätsmedizin Berlin, **S Kalok** Neurologisches Zentrum, Segeberger Kliniken, Bad Segeberg and **M Pause** Neurologisches Rehabilitationszentrum, Magdeburg, Germany

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Objective: To study the effects of augmented exercise therapy time for arm rehabilitation as either Bobath therapy or the impairment-oriented training (Arm BASIS training) in stroke patients with arm severe paresis.
Design: Single blind, multicentre randomized control trial.
Setting: Three inpatient neurorehabilitation centres.
Subjects: Sixty-two anterior circulation ischaemic stroke patients.
Interventions: Random assignment to three group: (A) no augmented exercise therapy time, (B) augmented exercise therapy time as Bobath therapy and (C) augmented exercise therapy time as Arm BASIS training.
Main measures: Main outcome measure: Fugl-Meyer arm motor score. Secondary measure: Action Research Arm Test (ARA). Ancillary measures: Fugl-Meyer arm sensation and joint motion/pain scores and the Ashworth Scale (elbow flexors).
Results: An overall effect of augmented exercise therapy time on Fugl-Meyer scores after four weeks was not corroborated (mean and 95% confidence interval (CI) of change scores: no augmented exercise therapy time ($n = 20$) 8.8, 5.2–12.3; augmented exercise therapy time ($n = 40$) 9.9, 6.8–13.9; $p = 0.2657$). The group who received the augmented exercise therapy time as Arm BASIS training ($n = 20$) had, however, higher gains than the group receiving the augmented exercise therapy time as Bobath therapy ($n = 20$) (mean and 95% CI of change scores: Bobath 7.2, 2.6–11.8; BASIS 12.6, 8.4 – 16.8; $p = 0.0432$). Passive joint motion/pain deteriorated less in the group who received BASIS training (mean and 95% CI of change scores: Bobath -3.2, -5.2 to -1.1; BASIS 0.1, -1.8–2.0; $p = 0.0090$). ARA, Fugl-Meyer arm sensation, and Ashworth Scale scores were not differentially affected.
Conclusions: The augmented exercise therapy time as Arm BASIS training enhanced selective motor control. Type of training was more relevant for recovery of motor control than therapeutic time spent.

Address for correspondence: T Platz, Klinik Berlin, Kladower Damm 223, 14089 Berlin, Germany.
e-mail: tplatz@zedat.fu-berlin.de

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Introduction

Arm paresis is a frequent sequel of brain damage (e.g., after stroke). Hemiparesis is one of the most important predictors of long-term disability.[1,2] Motor function of the affected arm can explain up to 50% of the variance in functional autonomy in stroke patients.[3] Arm paresis after stroke significantly contributes to activity limitations and restrictions of participation.[4]

A systematic review of studies that addressed the effects of augmented exercise therapy time in stroke rehabilitation indicated a small but favourable effect of augmented exercise therapy time on activities of daily living and walking speed, but not on dexterity.[5] A systematic review of randomized controlled trials that investigated the effects of exercise therapy for arm function in stroke patients stated that currently no definite conclusions about the effectiveness of exercise therapy on arm function in stroke patients can be drawn.[6] Thus, favourable training strategies and schedules for arm rehabilitation after stroke have yet to be determined.

Arm paresis shows a bimodal distribution with many patients with either mild or severe arm activity limitations: While many patients are not able to use their affected arm for any functional task, an equally considerable proportion can perform many manual tasks, but are clumsy.[7,8] Thus, a specific impairment-oriented training concept would have to provide at least two training strategies to deal with arm paresis after stroke. Such training methods have been developed as the Arm Ability training for patients with mild arm paresis and the Arm BASIS training for patients with severe arm paresis. Together these provide an impairment-oriented modular exercise therapy approach to arm paresis after brain damage.[9,10]

The Arm BASIS training is a systematic training developed by C Eickhof that aims to restore impaired functions with severe paresis, i.e., to restore the full range of nonsegmented and smooth active motion of all limb segments, to improve (rapid) force generation and its rapid modulation, to increase selectivity of motor control and endurance, to restore appropriate torque production across muscle groups for both dynamic and postural motion control and to restore interjoint co-ordination.[9,11]

An alternative approach for arm rehabilitation is the Bobath approach, a widely used physiotherapy method to treat hemiparesis after stroke. The Bobath therapy is a nonstandardized treatment approach for hemiparetic patients that based on the analysis of any individual's (motor) behaviour plans individually a treatment strategy that is meant to support the reacquisition of normal motor behaviour and that can be modified according to the individual's actual condition and any changes of the environment.[12]

The study addressed the questions whether (a) augmenting exercise therapy time for arm rehabilitation over a period of four weeks could enhance motor recovery, and (b) whether any favourable effect of augmented exercise therapy time would depend on the type of training provided (i.e., either Bobath therapy or the Arm BASIS training).

Methods

Design

This was a single blind, multicentre randomized control trial with random assignment of stroke patients with severe arm paresis to either (A) no augmented exercise therapy time, or augmented exercise therapy time as either (B) Bobath therapy or (C) Arm BASIS training (Figure 1).

Participants

From 1999 to 2002, patients after a first clinically apparent unilateral supratentorial anterior circulation ischaemic stroke in the subacute phase were recruited during inpatient rehabilitation treatment at one of three participating departments of neurological rehabilitation: (1) the department of neurological rehabilitation of the Charité–Universitätsmedizin Berlin, Germany, (2) the neurological (rehabilitation) centre of the Segeberger Kliniken, Bad Segeberg, Germany, and (3) the neurological rehabilitation centre (NRZ) in Magdeburg, Germany.

Patients were selected on the basis that (a) they had severe (incomplete) arm paresis (i.e., Fugl-Meyer Test Arm score[13] (except reflex activity related scores) between 5 and 34), (b) their acute stroke had occurred between three weeks and six months ago, (c) they had no more than mild speech comprehension deficit (i.e., Hemispheric Stroke

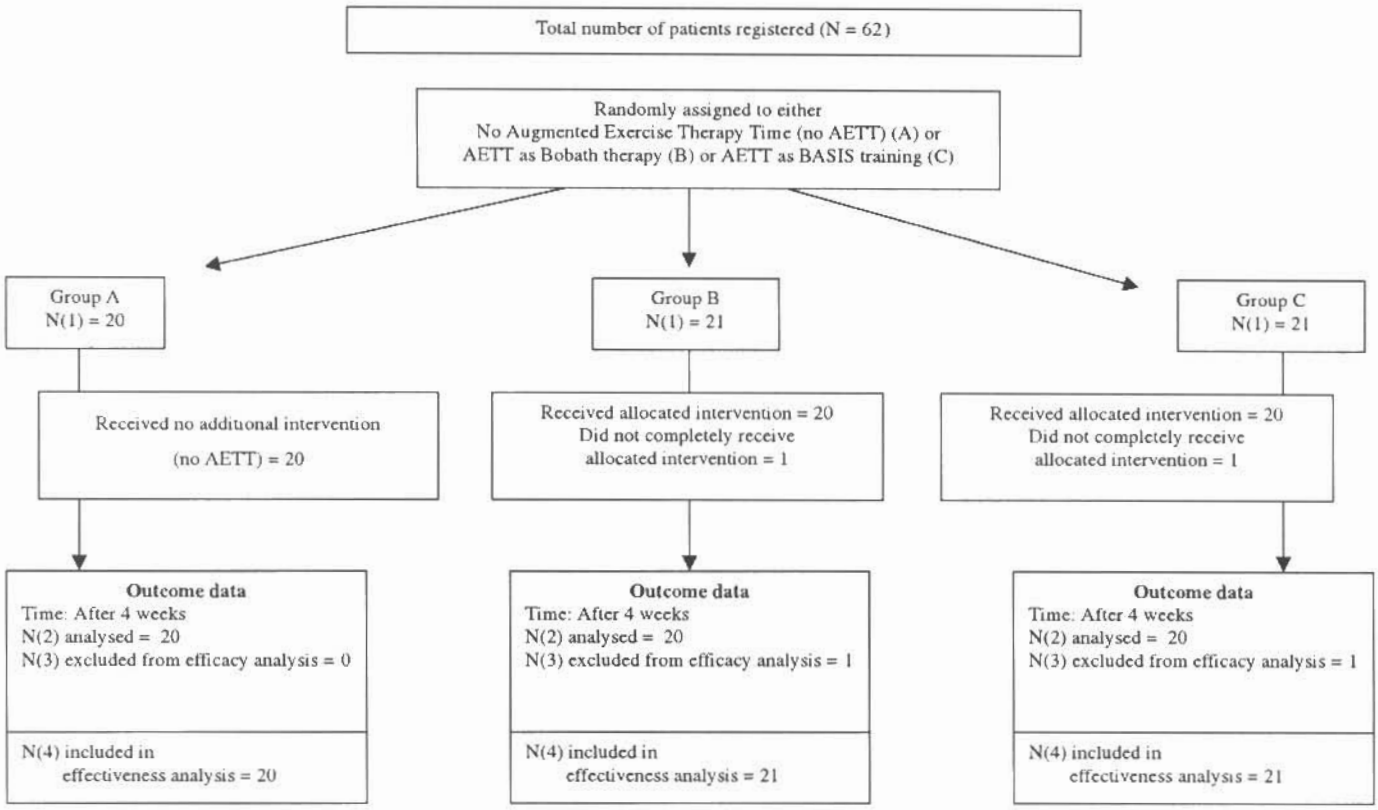

Figure 1 Flowchart of the study.

Scale,[14] comprehension score '2' or '0' (correctly following two out of three commands)), (d) they had no inability to perform the Fugl-Meyer test due to reasons not related to central arm paresis (e.g., contractures of arm joints).

Type of stroke was classified according to the Bamford criteria (i.e., lacunar (LACI), partial (PACI), or total anterior circulation infarct (TACI))[15] The Hemispheric Stroke Scale was used for the quantification of impairment after stroke in a more general sense.[14] The modified Barthel Index was used to document the patients' ability to cope with basic activities of daily living.[16]

All subjects gave informed consent to participate in the study that had received approval by the local ethics committee of each study centre.

Randomization

For the purpose of the study, two-thirds of the study patients received augmented exercise therapy time with 20 additional arm training sessions (each lasting 45 min) over the course of four weeks while the remaining patients received the usual treatment only (no augmented exercise therapy time). Study patients were randomly assigned to one of three groups: (A) receiving no augmented exercise therapy time, (B) receiving augmented exercise therapy time with conventional arm rehabilitation (augmented exercise therapy time Bobath), or (C) receiving augmented exercise therapy time with impairment-oriented arm rehabilitation (augmented exercise therapy time BASIS).

A random allocation sequence list was generated using a computerized random-number generator and stored outside of the study centres. Assignments were enclosed in sequentially numbered, opaque, sealed envelopes and stored at the central study centre in Berlin. Personnel who assessed eligibility, obtained informed consent and enrolled a patient in the trial had no knowledge about assignment. After recruitment, the appropriate envelope was opened and the randomization information given to the recruitment and training personnel of the enrolling study centre (but not to the primary central rater). The code was revealed to the researchers once recruitment, data collection and analyses were complete.

Interventions

During the four-week interval between pre- and posttest, all patients received the usual standard rehabilitation therapy. The treatment made use of different therapeutic concepts and addressed various issues such as activities of daily living, arm activities, stance and gait, speech and cognition.

Augmented exercise therapy time was provided as either Bobath therapy (augmented exercise therapy time Bobath) or Arm BASIS training (augmented exercise therapy time BASIS).

For the Bobath approach, a study manual served the experienced physiotherapists as the basis for the study treatment. Its design had been supervised by a senior Bobath instructor. The emphasis has been on control of muscle tone and recruitment of arm activity in functional situations with various positions (i.e., lying, sitting, standing, walking, both with and without objects and during unilateral or bilateral tasks).

The Arm BASIS training is a systematic repetitive training technique for hemiparetic patients.[9,11] During each training session, all degrees of freedom of the arm are repetitively trained across the full range of motion. The patient is encouraged to perform selective dynamic movements across the range of motion in individual planes of individual arm joints. The training is first without active postural stabilization of the limb to promote dynamic control. The therapist substitutes for any incapacity of the patient to perform movements actively and provides feedback about any movement success (in terms of selective dynamic motion) or failure. Once selective dynamic motion across the full range of motion of single joints has been re-established, the interplay between postural stabilization and dynamic control is trained, and finally multijoint co-ordination.

The training comprises three consecutive stages:

1) selective innervation for isolated motions without postural control,
2) selective innervation for isolated motions with postural control,
3) selective innervation for complex motions with postural control.

At each stage the various degrees of freedom of the arm are systematically and repetitively trained. At stage 1 single-joint movements are trained with concentric contractions, but not against gravity. The aim of stage 1 is to restore (fast and forceful as well as nonsegmented) dynamic motion control across the full range of motion for individual joints without postural control. Single joint motions are also trained in stage 2 of the Arm BASIS training. Now, however, dynamic and postural control are combined when patients ought to perform concentric, excentric and isometric contractions against and with gravity, against resistance, and when the moving limb is loaded with weights. The aim is to restore the full range of active motion for individual joints as well as their postural stabilization under both the influence of the limb's weight as well as external forces. Multijoint movements afford complex innervation pattern. These are specifically trained in stage 3. Here, combinations of concentric, excentric, and isometric contractions are necessary and have to be co-ordinated across limb segments. The aim is to restore well co-ordinated multijoint movements under both the influence of the limb's weight as well as external forces.

Outcome measures

As a primary outcome measure, the arm motor section of the Fugl-Meyer test has been selected (scores range from 0 to 66).[13,17,18] It is a test of the hemiplegic patient's ability to move the arm, including proximal arm, hand, and fingers, selectively. The subtests sensation and passive joint motion/pain have also been administered (ancillary measures). Inter-rater reliability in the current study was very high for the Fugl-Meyer motor, sensation, and passive joint motion/pain scores when assessed for 62 pretest assessments: intraclass correlation coefficients were above 0.95.

As secondary outcome measure, the Action Research Arm Test, a test that measures whether various smaller and larger objects can be successfully handled, had been selected (scores range from 0 to 57).[19] The test has 19 items that are ordered in four subtests that represent different aspects of upper limb function: Grasp, Grip, Pinch, Gross movement.

These assessments were performed by personnel from the lead clinical centre and were documented on video. Scoring was based on video information. This approach has previously been shown to produce reliable and valid scoring of the Fugl-

Meyer test and the Action Research Arm Test, including retest reliability.[20]

As an ancillary measure, the Ashworth Scale scores for elbow flexors were documented. This is a widely used measure of resistance to passive movement (and spasticity).[21]

Blinding

The primary central rater for outcome measures was blinded to treatment assignment for the duration of the study. More so, the rater scored the assessment videos without knowledge of time of testing (pretest or posttest). This was achieved by random number codes for each assessment.

Sample size

To have an 80% chance of detecting as significant (at the two-sided 5% level) a five-point difference in change scores between either two compared groups in the mean Fugl-Meyer arm motor score, with an assumed standard deviation of 5, 16 patients in each group were required. Twenty patients in each group (60 in total) were planned to become enrolled to allow for imprecision of the estimation. To secure the efficacy analysis it was predetermined to substitute any patient who did not complete the study protocol.

Statistical methods

The primary analysis was an efficacy analysis and involved all patients who were randomly assigned and completed the study protocol.

Characteristics of the study group were summarized with descriptive statistics. Differences in baseline characteristics and concurrent exercise therapy between the three randomized groups were analysed with chi-squared test or one-way ANOVA as appropriate.

General linear models including multiple regressions within a repeated-measures ANOVA design were used to assess the effect of augmented exercise therapy time and type of training on motor recovery (Fugl-Meyer test or Action Research Arm Test): Repeated measures were pre- and posttest motor scores (dependent variables, factor 'time'). Independent variables were the experimental factors 'augmented exercise therapy time' and 'type of training' (augmented exercise therapy time Bobath or augmented exercise therapy time BASIS) nested within the factor 'augmented exercise therapy time'. Both severity of motor impairment at baseline (Fugl-Meyer test, arm motor score) and time since onset of stroke were used as covariates because they are known to modify recovery.[7,8,13] F-values presented for these models are partial F-values (based on type III sums of squares).

Predefined ancillary analyses included differences regarding concurrent motor therapy, any treatment effects and side-effects on sensation, passive range of motion and joint pain, or spasticity. These effects were analysed with the general linear models as described above.

An additional intention-to-treat analysis (with the general linear model as described above) was planned for the primary outcome measure and effects of 'augmented exercise therapy time' and 'type of training'. It was predefined to be based on data of all randomized patients and if necessary on the 'last observation carried forward'-approach (LOCF) for dealing with missing values in clinical trials.[22]

Relative differences of change scores across groups of less than 20% were regarded as not clinically significant.

Role of the funding source

The study sponsor had no role in study design; in the collection, analysis, and interpretation of data; in the writing of the report; and in the decision to submit the paper for publication.

Results

Numbers of participants who were randomly assigned in one of the three groups received the intended treatment, completed the study protocol, and were analysed for the primary and secondary outcome are presented in the flowchart (Figure 1). Compliance to intervention was high with only one patient in each augmented exercise therapy time group who did not complete the study intervention. Characteristics of the participants in the three groups are comparable (Table 1).

Thirty-seven patients had been recruited in the rehabilitation centre in Berlin, 21 in Magdeburg, and two in Bad Segeberg. Randomized

Table 1 Characteristics of participants

	No AETT ($n = 20$)	AETT Bobath ($n = 20$)	AETT BASIS ($n = 20$)	p-values[a]
Gender (f/m)	7/13	11/9	11/9	0.3437
Stroke (LACI, TACI, PACI)	5/3/12	8/5/7	7/3/10	0.6026
Affected arm (left/right)	12/8	13/7	13/7	0.9307
Age (mean (SD))	60.9 (14.0)	60.6 (10.5)	62.5 (12.9)	0.8758
Weeks after stroke (mean (SD))	4.6 (1.6)	6.5 (3.9)	6.2 (3.6)	0.1508
Stroke scale (mean (SD))	27.9 (8.0)	30.6 (8.6)	29.9 (7.9)	0.5651
FM motor (mean (SD))	22.8 (11.2)	22.8 (10.5)	22.8 (9.1)	0.9998
FM sensation (mean (SD))	9.8 (2.6)	9.6 (2.3)	9.7 (2.6)	0.9662
FM joint (mean (SD))	44.8 (4.3)	43.1 (4.8)	43.2 (5.5)	0.4799
Ashworth (mean (SD))	0.5 (0.8)	0.5 (0.7)	0.6 (0.8)	0.9120
ARA (mean (SD))	6.4 (6.4)	9.6 (9.3)	8.0 (8.8)	0.4666
Barthel Index (mean (SD))	78 (18)	77 (18)	70 (25)	0.3537

[a]p associated with chi-squared test for categorical variables and with one-way ANOVA for continuous variables.
AETT, augmented exercise therapy time; LACI, lacunar anterior circulation infarct; TACI, total anterior circulation infarct; PACI, partial anterior circulation infarct.
Stroke scale (scores range from 0 [no] to 100 [most severe clinical impairment]); FM motor, Fugl-Meyer test, arm motor score (scores range from 0 [no] to 66 [normal selective motor control]); FM sensation, Fugl-Meyer test, arm sensation score (scores range from 0 [no] to 12 [normal sensation]); FM joint, Fugl-Meyer test, arm joint motion/pain score (scores range from 0 [only few degrees of range-of-motion/pronounced pain] to 48 [normal ROM/no pain]); Ashworth scale (scores range from 0 [normal tone] to 4 [fixed rigid position]); ARA, Action Research Arm test (scores range from 0 [no] to 57 [normal arm activities]), Modified Barthel Index (scores range from 0 [no ability] to 100 [full ability to copy with basic ADLs]).

groups were comparably distributed across centres (chi-squared test, $p > 0.85$).

The group mean scores for all outcome measures (and their standard deviation) at both pretest (week 0) and posttest four weeks later as well as their change scores (and 95% confidence intervals) are presented in Table 2.

The effects of augmented exercise therapy time and of any effect of the specific therapeutic techniques on Fugl-Meyer arm motor scores were assessed by ANOVA for repeated measures. Overall improvement over time (mean and 95% CI of change scores: 9.5, 7.2–11.8; $F(1,55) = 4.72$, $p = 0.0341$) was statistically significant while its interaction with 'augmented exercise therapy time' was not ($F(1,55) = 1.26$, $p = 0.2657$). The interaction of factors 'time' and 'type of training' (Bobath training or Arm BASIS training) nested within the factor 'augmented exercise therapy time' was statistically significant (mean and 95% CI of change scores: Bobath 7.2, 2.6–11.8; BASIS 12.6, 8.4–16.8; $F(1,55) = 4.28$, $p = 0.0432$). Thus, the effects of the Arm BASIS training (group C) were documented to be superior to the Bobath treatment (group B). In summary, the data analysis suggests a specific effect of augmented exercise therapy time in the form of Arm BASIS training only. The simultaneously assessed interaction of factor 'time' and either covariate ('time after stroke' or 'Fugl-Meyer baseline scores') was statistically significant with lower motor improvement in more severely affected patients ($F(1,55) = 7.60$, $p = 0.0079$) and patients with longer time post stroke at study entry ($F(1,55) = 5.76$, $p = 0.0198$).

Any treatment effect on the secondary outcome measure (i.e., the Action Research Arm Test) were analysed in the same way. No overall functional improvement could be corroborated (factor 'time': $F(1,55) = 0.04$, $p = 0.8377$). Neither augmented exercise therapy time nor either therapeutic method enhanced motor activity (interaction of the factors 'time' with either 'augmented exercise therapy time' or 'type of training' nested within the factor 'augmented exercise therapy time': $F(1,55) < 0.9$, $p > 0.35$). Time after stroke did not modify functional improvement (interaction of the factor 'time' with 'time after stroke': $F(1,55) = 1.53$, $p = 0.2214$) while level of impairment at baseline clearly modified functional improvement (interaction of the factor 'time' with 'Fugl-Meyer baseline scores': $F(1,55) = 23.66$, $p < 0.0001$): patients with less impairment at baseline were more likely to achieve functional

Table 2 Mean (SD) scores and mean (95% CI) differences within groups for all outcome measures

Outcome	Scores						Differences within groups		
	Week 0			Week 4			Week 4–Week 0		
	No AETT ($n=20$)	Bobath ($n=20$)	BASIS ($n=20$)	No AETT ($n=20$)	Bobath ($n=20$)	BASIS ($n=20$)	No AETT ($n=20$)	Bobath ($n=20$)	BASIS ($n=20$)
FM motor	22.8 (11.2)	22.8 (10.5)	22.8 (9.1)	31.6 (15.7)	30.0 (16.4)	35.4 (15.7)	8.8 (5.2–12.3)	7.2 (2.6–11.8)	12.6 (8.4–16.8)
ARA	6.4 (6.4)	9.6 (9.3)	8.0 (8.8)	17.5 (16.3)	17.4 (16.0)	18.6 (17.7)	11.2 (5.9–16.4)	7.8 (3.1–12.4)	10.7 (4.7–16.6)
FM sensation	9.8 (2.6)	9.6 (2.3)	9.7 (2.6)	10.9 (1.4)	9.9 (2.4)	10.6 (2.2)	1.1 (0.2–1.9)	0.3 (−0.6–1.2)	0.9 (0–1.8)
FM joint	44.8 (4.3)	43.1 (4.8)	43.2 (5.5)	42.3 (4.4)	40.0 (5.8)	43.3 (3.9)	−2.5 (−4.8–−0.2)	−3.2 (−5.2 to −1.1)	0.1 (−1.8–2.0)
Ashworth	0.5 (0.8)	0.5 (0.7)	0.6 (0.8)	0.4 (0.6)	0.6 (0.9)	0.4 (0.7)	−0.2 (−0.5–0.2)	0.2 (−0.4–0.7)	−0.2 (−0.6–0.2)

For explanations see Table 1.

gains as further indicated by a regression of Fugl-Meyer baseline scores (FM) on Action Research Arm Test difference scores (ARAdif) (ARAdif = $-4.3+0.62 \times$ FM).

An additional intention-to-treat analysis for treatment effects on Fugl-Meyer arm motor scores was based on the data of 62 patients who were randomized. Overall, augmented exercise therapy time did not enhance motion control, while again the effect of 'type of training' was significant (outcome measure Fugl-Meyer arm motor score, interaction of the factors 'time' with either 'augmented exercise therapy time' ($F(1,57) = 1.08$, $p = 0.3023$) or 'type of training' nested within the factor 'augmented exercise therapy time' $F(1,57) = 4.79$, $p = 0.0328$).

The amount of concurrent motor therapy units (i.e., occupational or physiotherapy as either individual or group training within the interval of four weeks from pretest to posttest) was comparable across groups (mean (SD) of motor therapy units: 42.2 (12.0) for the group with no augmented exercise therapy time, 40.4 (9.6) for the group with additional Bobath therapy, 41.8 (14.2) for the group with additional BASIS training; $F(2,57) = 0.12$, $p = 0.8867$).

Somatosensory function was not changed from pre- to posttest (factor 'time': $F(1,55) = 0.02$, $p = 0.8890$), nor were changes of somatosensory function significantly influenced by augmented exercise therapy time or either therapeutic method (interaction of the factors 'time' with either 'augmented exercise therapy time' or 'type of training' nested within the factor 'augmented exercise therapy time': $F(1,55) < 1.0$, $p > 0.32$).

Similarly, resistance to passive motion (spasticity) was not changed from pre- to posttest (factor 'time': $F(1,55) = 0.00$, $p = 0.9617$), nor were changes of spasticity significantly influenced by augmented exercise therapy time or either therapeutic method (interaction of the factors 'time' with either 'augmented exercise therapy time' or 'type of training' nested within the factor 'augmented exercise therapy time': $F(1,55) < 1.6$, $p > 0.21$).

Finally, passive joint motion and joint pain became on average somewhat worse in the study population ($F(1,55) = 25.09$, $p < 0.0001$). The effect was bigger in the group who received augmented exercise therapy time as Bobath therapy than in the group that received augmented exercise therapy time as BASIS training (mean and 95% CI of change scores: Bobath -3.2, -5.2 to -1.1; BASIS 0.1, -1.8 to 2.0; $F(1,55) = 7.34$, $p = 0.0090$).

Discussion

Key findings

Sixty patients with severe arm paresis in the subacute phase after a first supratentorial anterior circulation ischaemic infarct completed this study. They all received inpatient rehabilitation treatment for the study interval of four weeks. They were randomly assigned to receive either no additional arm rehabilitation beyond the standard treatment, or to receive 20 additional therapeutic units each lasting 45 min to promote arm recovery (i.e., to receive augmented exercise therapy time for their paretic arm). This augmented exercise therapy time was provided either in the form of Bobath therapy or as a newly designed impairment-oriented training, the Arm BASIS training. A general effect of augmented exercise therapy time on motor recovery could not be substantiated. Augmented exercise therapy time in the form of the Arm BASIS training, however, proved to be superior to augmented exercise therapy time as Bobath therapy. Thus, only augmented exercise therapy time as Arm BASIS training exerted a favourable effect on motor control (i.e., the ability to perform selective arm movements). This effect was specific for the motor domain (did not affect somatosensation) and did not transfer to arm function (i.e., the ability to handle objects). Adverse effects with

Clinical messages

- Exercise therapy time is not the only key factor in motor rehabilitation.
- The specific content of training may be more important for the recovery of motion control among poststroke patients with severe arm paresis than the therapeutic time spent for motor rehabilitation.

regard to spasticity or passive range of motion and joint pain were not induced by the Arm BASIS training. It rather seemed to exert a protective effect on passive joint motion and pain compared with augmented exercise therapy time as Bobath therapy.

Consideration of possible mechanisms and explanations

The Bobath therapy is a nonstandardized treatment approach for hemiparetic patients. Based on the analysis of any individual's (motor) behaviour, a treatment strategy is individually planned that is meant to support the reacquisition of normal motor behaviour and will be modified according to the individual's actual condition and any changes of the environment.[12] The Bobath therapy is designed to be comprehensive in taking into account perception, balance, movement and tone, to mention a few core aspects. While being open for 'online' adjustments in the treatment of patients, the decisions about specific treatment techniques are left to the individual therapist. She or he decides how to control muscle tone and how to achieve recruitment of arm activity in functional situations with various positions (i.e., lying, sitting, standing, walking, both with and without objects and during unilateral or bilateral tasks). While providing a chance to adjust treatment to any individual's specific circumstances there might be a risk for not necessarily providing key elements for motor recovery.

The Arm BASIS training is quite different in nature.[9,11] It is highly standardized with a three stage training strategy that addresses systematically selective dynamic and postural voluntary motor control across all limb segments with a repetitive training structure. It reduces the motor affordances to start with, provides therapeutic help while still requiring key control efforts by the patient, and guides towards appropriate innervatory behaviour by feedback. Full dynamic smooth and nonsegmented motion control for each basic limb motion is promoted first, the combined dynamic and postural control for individual limb segments is trained and restored next. Only then will multisegment motions be trained. The training structure is a reflection of our knowledge about deficient motor control in central paresis that accumulated over the past decades and is thus highly specific and impairment-oriented.[9]

As has been noted above, the favourable effect of augmented exercise therapy time as Arm BASIS training on arm motor control did not transfer to arm function (i.e., the ability to handle objects). In patients with severe arm paresis improvements in the ability to move the arm selectively do not necessarily imply that objects can more skilfully be handled until a certain level of motor control has been achieved.[23]

Comparison with relevant findings from other published studies

With regard to Bobath therapy, the observations of the present study are in line with other recent evidence indicating (a) that increasing exercise therapy time with Bobath therapy in stroke patients does not necessarily enhance recovery,[24] and (b) that repetitive (robot-aided) training of simple arm movements can accelerate motor recovery more than treatment according to the Bobath approach.[25]

With regard to Arm BASIS training, there is indeed accumulating evidence showing that patients with severe arm paresis can benefit from repetitive training schedules, whether exercise therapy,[23] robot-aided therapy,[25,26] or neuromuscular electrical stimulation[27,28] (for review see also ref. 29). The effect that has been demonstrated for the Arm BASIS training is relatively large: While 12 h of robot-aided therapy (for shoulder and elbow motions) within a month induced on average a differential gain of < 2 Fugl-Meyer points, 15 h of Arm BASIS training induced on average a differential gain of > 4 Fugl-Meyer points. This effect might be caused by the more comprehensive treatment approach by the Arm BASIS training that addresses both proximal and distal arm and hand movements and provides feedback about motion control, but could also be due to the fact that the patients had been treated earlier after stroke.

Limitations of the study

A limitation that is important to note is the lack of demonstration of long-term effects. The best way to investigate the long-term (functional) benefit of a training such as the Arm BASIS training would be to provide it over an extended

period (several months) until more functional gains have been achieved. Within the current study context this was not feasible however.

Clinical and research implications

The major clinical implication of the study might be that type of training may be more important for the recovery of selective motion control after stroke than therapeutic time spent. Fugl-Meyer pre–post difference scores were increased by the Arm BASIS training by more than 50% on average. Thus, there is reason to assume that the treatment could have a clinically relevant impact on stroke rehabilitation.

The training had been selected as an impairment-oriented training because its structure and content reflect the specific neurobiological deficits of the specific clinical problem (severe arm paresis).[9] Its demonstrated efficacy and effectiveness (intention-to-treat analysis) show that rehabilitation therapies can benefit from neuroscience applied to clinical practice.

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