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# Assessment of motor and process skills reflects brain-injured patients' ability to resume independent living better than neuropsychological tests

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*Objective* – To compare recovery of cognitive functions and activities of daily living during the first year of rehabilitation after severe brain trauma. *Methods* – Sixteen patients were evaluated by neuropsychological tests and occupational performance (assessment of motor and process skills, AMPS) on admission to the rehabilitation centre and 3, 6 and 12 months later. *Results* – Cognitive functions improved continuously. Motor skills recovered rapidly and were relatively stable after 3 months. For process skills recovery was protracted. Six of 15 patients were still below the cut-off level after 12 months. Eleven of 13 patients deteriorated regarding process skills after leaving the rehabilitation centre. *Conclusion* – AMPS gives a different view of the patient's restitution than neuropsychological tests and may be a better indicator of the patients' ability to resume independent living. The deterioration of process skills post-rehabilitation suggests that lasting contact in an outpatient setting might facilitate return to social life.

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Key words: head injury; neuropsychological test; activities of daily living; assessment of motor and process skills

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Severe traumatic brain injury (TBI) often leads to permanent focal neurological deficits and cognitive impairments, which may interfere with the individual's ability to live an independent life (1). In most patients focal neurological deficits have a limited influence on the quality of life and several studies have shown that remaining neuropsychological sequelae of cognitive and behavioural type constitute the major impediment to assimilation into a productive social life (1–5). Knowledge is, however, limited with regard to the initial recovery of specific neuropsychological deficits and its relation to patient's capacity to carry out activities of daily living (ADL). In the present study, patients with severe TBI were followed by multidisciplinary assessments (clinical, neurophysiological, neuropsychological, and functional – ADL) from the time of injury to 1 year after admission to

post-acute rehabilitation. The aims of the study were to evaluate and compare the restitution of specific cognitive functions and the recovery ADL performances regarding motor and process skills. The latter was obtained according to the method developed for occupational therapists: assessment of motor and process skills (AMPS) (6).

## Patients and methods

The study included 16 consecutive patients, three women and 13 men, with a mean age of 31 years (range 15–48 years) primarily treated in the Department of Neurosurgery, Lund University Hospital, for severe TBI. Ten of the patients were injured in traffic accidents, four were fall accidents, one was injured in a riding accident and one was due to a self-inflicted gun injury. Data showing

type of lesion, coma depth and duration, and duration of rehabilitation are listed in Table 1.

After finishing the treatment in the intensive care unit all patients were transferred directly to the rehabilitation centre. A team including occupational therapists, psychologists, physiotherapists, speech therapists, nurses, and doctors treated the patients in a unit designed for rehabilitation of brain injuries. The duration of rehabilitation ranged from 67 to >365 days (Table 1).

Study design

In the Department of Neurosurgery the patients were assessed regarding coma depth, coma duration, and the results of repeated CT-scanning. Coma depth on admission and the duration of coma were assessed with the Reaction Level Scale, RLS-85 (7) according to the clinical routines in Sweden. During the first year of rehabilitation the patients were subjected to neuropsychological evaluations on admission to the rehabilitation centre (measurement I), and 3 (measurement II), 6 (measurement III), and 12 (measurement IV) months later. The study included evaluations of ADL according to AMPS (6), and measurements of regional cerebral blood flow (CBF) with three-dimensional SPECT measurements (Cerotec) (8) as well as a two-dimensional (133Xenon) technique (9). Routine clinical and neurological evaluations were performed at each measurement occasion. In

this report we present the results of the neuropsychological and the AMPS evaluations. The results of the CBF measurements have been reported (10).

Neuropsychological assessments

A comprehensive neuropsychological evaluation was performed to determine the quality and nature of cognitive functioning. Standard instruments were used to evaluate verbal intellectual capacity, learning and memory functions, visuo-spatial organization and constructional capacity, perceptual speed/accuracy and logical reasoning capacity, and cognitive flexibility, attention and concentration (11–18). The test battery was administered on the four occasions according to standard procedures and evaluation principles. Parallel versions were used at follow-up measurements when possible.

Assessment of motor and process skills

The AMPS is designed to measure a person's quality of performance of ADL tasks (6). Personal activities of daily living (PADL) as well as instrumental activities of daily living (IADL) are included in the tasks. The AMPS consists of two domains of occupational performance: ADL motor and ADL process skills. Motor skills are the observable goal-directed actions the person enacts during the performance of ADL tasks in order to move oneself or the task objects. Process skills are the observable actions of performance the person enacts to logically sequence the actions of ADL task performance over time, select and use appropriate tools and materials, and adapt his/her performance when problems are encountered.

The occupational therapist (OT) plans the assessment and starts with an interview by asking the person what type of tasks the person routinely performs during the day. The person chooses at least two tasks from the AMPS manual, sets up the test environment and is then observed (in this study video recorded) when performing the tasks. The OT scores the performance of each motor and process item on a 4-point scale. The person is scored 4 = competent, when the person performs the task without evidence of increased effort, decreased efficiency, or lack of safety. If the examiner questions the effectiveness the performance is scored 3 = questionable. Ineffective performance that disrupts or interferes with the action is scored 2. Marked deficient performance that impedes the action progression and yields unacceptable outcome is scored 1. The raw scores are

**Table 1** Demographic data, neurological characteristics and duration of rehabilitation in 16 patients with severe traumatic brain lesions

Patient no.	Age (years)	Gender (m/f)	Lesion type	Coma RLS	Coma days	Rehabilitation days
1	24	m	Subdural	2	5	134
2	30	f	Intracerebral	4	10	>365
3	45	f	No mass	2	11	146
4	43	m	Intracerebral	3	1	203
5	48	f	No mass	2	0	71
6	15	m	No mass	4	7	84
7	31	m	Epidural	7	20	>365
8	40	m	No mass	4	7	94
9	19	m	Intracerebral	5	16	137
10	38	m	No mass	7	7	251
11	17	m	No mass	4	2	253
12	19	m	No mass	4	14	156
13	21	m	Intracerebral	7	15	>365
14	39	m	Epidural	6	3	67
15	37	m	Intracerebral	3	7	156
16	31	m	Subdural	7	12	177

Age refers to the patient's age at the time of injury. Lesion type refers to the location of the acute, traumatic haematoma (epidural, subdural, intracerebral) or general brain swelling in the absence of a focal mass (no mass). Coma RLS refers to coma depth according to RLS 85 (7) on admission to the Department of Neurosurgery. Rehabilitation refers to the duration of treatment in the Brain Injury Rehabilitation Unit.

then entered into the AMPS computer-scoring program and a Rasch analysis (6, 19) converts the person's ordinal raw AMPS skill item score into linear person ability measures. The person's ability measures are adjusted by the computer programs to account for: (a) skill item difficulty, (b) task challenge, and (c) the individual evaluator.

#### Statistics

All values are given as mean  $\pm$  standard deviation (SD). The AMPS data were processed in a Rasch analysis. Intra group comparisons were made by paired *t*-test.

### Results

#### Cognitive improvement over time

The mean performances and standard deviation on each neuropsychological test at admission, and after 3, 6, and 12 months are given in Table 2. A few patients were not able to participate at all tests. The number of excluded patients at each test is given in the table.

Continuous improvements of the mean results were obtained for all neuropsychological tests. In the logical reasoning test (SRB 2) and the memory for design test (MFD) a performance close to the normal limit was observed already at the first test occasion. For these two tests and for the vocabulary test (CVB), digit symbol test (DS), paired associates (PA), logical memory (MP), and the visual retention test (VRT) the average performance normalized during the study period. For the colour word test (CWT), the digit span forwards (Dig. A), and the digit span reversed (Dig. B) the average results did not completely reach the normal limit.

#### Changes in motor and process abilities

The AMPS data regarding motor and process skills are shown in Fig. 1 for each individual patient. In accordance with practice the AMPS data are given in logits (6, 19). Altogether four of the patients missed one test occasion each. On admission mean performance was  $1.46 \pm 1.24$  logits for motor skills. It increased to  $2.53 \pm 1.03$  logits after 3 months and remained fairly constant at this level during the study period. The cut-off level for independent living (indicated in the figure) is regarded to be 2.0 logits for motor skills (20). Seven patients scored above this level already on admission to the rehabilitation centre. Five of 15 patients were below the cut-off level at the assessment after 3 months, five of 14 and three of 15 at the assessments after 6 and 12 months, respectively.

For process skills mean performance was  $0.26 \pm 1.29$  logits on admission. It increased to  $1.02 \pm 0.68$  logits and  $1.16 \pm 0.50$  logits after 3 and 6 months, respectively. For process skills the cut-off level for independent living (indicated in the figure) is regarded to be 1.0 logits (20). Thirteen of 16 patients had process ability measures below the cut-off level on admission. Seven out of 15 patients were below cut-off level at the assessment after 3 months. Five of 14 and six of 15 patients were below the cut-off level at the assessments after 6 and 12 months, respectively.

A significant improvement in motor skills ( $P < 0.001$ ) as well as in process skills ( $P < 0.05$ ) was obtained between the evaluation on admission and the test 3 months later.

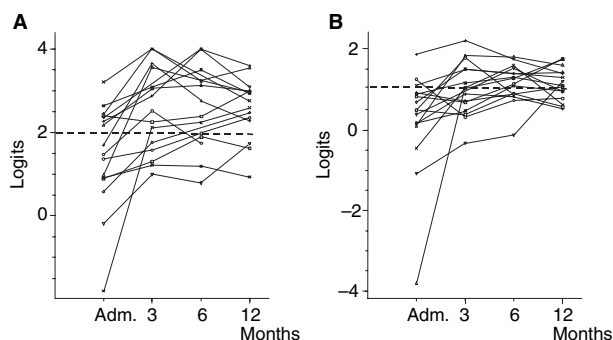
#### Influence of continued rehabilitation

To evaluate the specific effects of rehabilitation services we compared the individual data for each

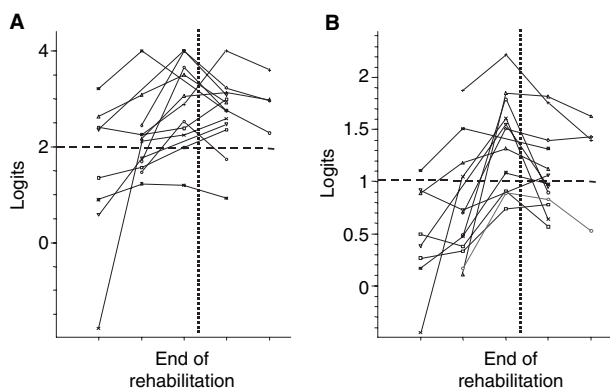
**Table 2** Performance on each neuropsychological test at admission (I), and after 3 (II), 6 (III), and 12 (IV) months

Cognitive function	I (admission)	II (3 months)	III (6 months)	IV (12 months)	Subnormal performance
Reasoning (SRB 2) ( <i>Excl.</i> )	15.5 (8.8) (1)	20.7 (4.5)* (1)	23.3 (2.5)	24.3 (10.9)	Below 14
Vocabulary (CVB)	15.9 (9.9)**	23.2 (8.6)	23.5 (6.8)	25.1 (7.4)	Below 21
Colour word test (CWT) ( <i>Excl.</i> )	203.3 (126.6)* (4)	163.4 (79.7) (3)	187.5 (99.7)	173.9 (101.1)	Above 170
Digit symbol test (DS)	26.8 (13.5)**	34.1 (14.2)	39.7 (9.0)*	44.7 (15.8)	Below 36
Paired associates (PA)	11.5 (9.5)*	14.9 (8.9)	17.5 (8.3)*	19.5 (6.0)	Below 17
Confabulation (C)	7.4 (6.5)*	4.5 (3.3)	4.1 (3.7)	3.9 (3.5)	–
Logical memory (MP)	7.4 (5.7)	8.7 (4.9)	8.9 (5.4)**	10.4 (5.4)	Below 9.3
Digit span forwards (Dig. A)	4.8 (2.3)	5.3 (1.8)	5.7 (1.0)	6.0 (0.9)	Below 7.0
Digit span reversed (Dig. B)	2.1 (2.1)	2.7 (1.8)*	3.2 (1.8)	3.4 (1.5)	Below 5.3
Memory for designs (MFD) ( <i>Excl.</i> )	3.5 (4.9) (2)	2.3 (3.9)* (2)	1.6 (3.2) (2)	1.9 (3.3)	Above 4
Visual retention test (VRT) ( <i>Excl.</i> )	6.9 (3.9) (2)	4.8 (3.4) (2)	3.4 (3.1) (2)	2.6 (2.5) (1)	Above 6
Rey complex figure (Rey)	12.2 (5.2)***	9.2 (4.9)*	8.5 (4.4)	8.3 (4.8)	–

Data are given as mean (standard deviation within parentheses). *Excl.* indicates the number of patients who could not accomplish the test. Inter-measurement comparisons by paired *t*-test: \* $P < 0.05$ ; \*\* $P < 0.01$ ; \*\*\* $P < 0.001$ .



**Figure 1.** Evaluation of motor skills (A) and process skills (B) according to assessment of motor and process skills (AMPS). The figure illustrates the changes for all 16 studied patients and data are according to praxis given in logits. The evaluations were performed at admission to the rehabilitation centre (Adm.) and 3, 6, and 12 months later. The individual patients are identified by the same symbols in Fig. 1A,B. The cut-off level for independent living (2.0 logits for motor skills; 1.0 logits for process skills) are indicated (20).



**Figure 2.** Evaluation of motor skills (A) and process skills (B) according to assessment of motor and process skills (AMPS). The data are according to praxis given in logits. The end of the rehabilitation period is indicated in the figures and the individual patients are identified by the same symbols in Fig. 2A,B. Since three patients were still in the rehabilitation unit 12 months after admission Fig. 2 shows the data for 13 patients. The cut-off level for independent living (2.0 logits for motor skills; 1.0 logits for process skills) are indicated (20).

patient immediately before discharge from the rehabilitation centre with their final performances (Fig. 2). Three patients who were treated in the rehabilitation centre for more than 365 days (i.e. the whole study period) were excluded from this comparison. AMPS data for motor as well as process skills were used and from the neuropsychological tests the individual results from the PA and CWT tests were used. Regarding process skills 11 of 13 patients deteriorated after leaving the rehabilitation centre (mean levels  $1.42 \pm 0.38$  logits and  $1.11 \pm 0.44$  logits, respectively;  $P < 0.05$ ). For motor skills nine of 13 patients deteriorated (mean levels  $2.89 \pm 0.99$  logits and

$2.59 \pm 0.78$  logits, respectively; n.s.). Regarding the neuropsychological PA test (12) one of 13 patients deteriorated after discharge and mean performance improved (mean level  $16.2 \pm 9.1$  and  $20.9 \pm 5.3$ , respectively;  $P < 0.05$ ). In the CWT (16, 17) three of 13 patients deteriorated after discharge (mean level  $173.6 \pm 85.8$  and  $156.8 \pm 71.5$ , respectively; n.s.).

## Discussion

The studied group of 16 patients is representative of patients with severe TBI treated in our neurosurgical department with regard to age, gender, and type of lesion (1). The high scores on RLS-85 and the long coma duration in several of the patients document the severity of the lesions (Table 1). The patterns of cognitive recovery obtained in this study should thus illustrate those for patients with severe TBI and the relation between the cognitive test results and the ADL performances should be relevant for this group of patients.

### Recovery profiles of cognitive functions

Deficits of memory for new information constitute a major problem for the brain-injured patients. The present study shows that normal performance was obtained on most neuropsychological tests 1 year after injury (Table 2) although the patients had suffered severe brain trauma. However, for the verbal memory variables, several patients did not reach the lower normal limit at measurement IV. This was particularly obvious for the logical memory subtest and the digit span reversed of the Wechsler Memory Scale, functions that require intact continuous verbal memory as well as abstract thinking and concentration capacity. The verbal memory variables contrast with the visual-spatially based memory functions, where most patients had reached normal values at the 6-month assessment.

The tests of short-term memory (PA) and cognitive/associative flexibility and susceptibility to interference (CWT) were chosen for the comparison with the AMPS data. For the PA test a significant improvement was seen across the whole period of measurements. For the CWT the results were initially subnormal and, although a continuous improvement was observed, a complete normalization was not obtained.

### Recovery profiles of motor and process abilities

As illustrated in Fig. 1 average motor ability measures for the whole group of patients were

relatively stable after 3 months. Already at this time 10 of 15 patients were above the cut-off level for independent living. At the 12-month follow up 12 of 15 patients were above the cut-off level indicating that impairment of motor skills should have only a limited impact on the patients' ability to perform ADL activities. For process skills recovery appeared to be protracted: at the 12-month follow up six of 15 patients were still below the cut-off level for independent living.

The finding that 11 of 13 patients deteriorated regarding process skills after leaving the rehabilitation centre was unexpected (Fig. 2B). The finding is supported by the simultaneous statistically significant decrease in the mean level of process skills for the whole group of patients. The observation is of particular interest since a similar deterioration was not observed in the neuropsychological assessments.

A relation between the patients' cognitive abilities and their ability to accomplish ADL activities according to AMPS might have been expected and was recently shown in a study of stroke patients (21). A tendency towards parallel improvements regarding neuropsychological test results and AMPS were also observed in the present study (cf. Table 2 and Fig. 1). However, the variables evaluated in the neuropsychological test battery appeared to be rather robust and did not deteriorate after the patients had left the rehabilitation centre. This contrasts to the AMPS evaluations. These evaluations are known to be sensitive to environmental changes and it has been described that process skills are affected to a greater degree than motor skills when comparing occupational performance between clinical and home settings (22, 23). The fact that individuals with acquired brain injuries are highly sensitive to stressful changes including variations in the environment when performing ADL activities suggests that AMPS may give a better indication of the patient's ability to resume independent living than neuropsychological testing alone. Our observation that the patients' performance regarding process skills deteriorated after leaving the rehabilitation centre suggests that intermittent, lasting contact in an outpatient setting might facilitate return to social life.

Admittedly the present study is based on a small number of patients. The hypothesis that AMPS may give a better indication of the patient's ability to resume independent living than neuropsychological testing alone should thus be tested in a larger group of brain injured patients and include a comparison with the actual return to an independent active social life.

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