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PREDICTING MOBILITY OUTCOME ONE YEAR AFTER STROKE: A PROSPECTIVE COHORT STUDY

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Objective: **To develop a prognostic model to predict mobility outcome one year post-stroke.**
Design: **Prospective cohort study in patients with a first-ever stroke admitted for inpatient rehabilitation.**
Patients: **A total of 217 patients with stroke (mean age 58 years) following inpatient rehabilitation in 4 rehabilitation centres across the Netherlands.**
Methods: **Mobility was measured using the Rivermead Mobility Index at one year poststroke. Included independent variables were: patient and stroke characteristics, functional status, urinary incontinence, sitting balance, motor and cognitive function. Univariate and multivariate linear regression analyses were performed in a model-developing set ($n = 174$) and the model was validated in cross-validation set ($n = 43$).**
Results: **Total Rivermead Mobility Index score at one year post-stroke was predicted by functional status, sitting balance, time between stroke onset and measurement, and age. The derived model predicted 48% of the variance, while validation in the cross-validation set resulted in an adjusted R^2 of 0.47.**
Conclusion: **The present prospective study shows that outcome of mobility one year after stroke can be predicted validly by including functional status, sitting balance, moment of admission to the rehabilitation centre after stroke onset and age.**

Key words: cerebrovascular disorders, rehabilitation, prognosis, mobility.

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INTRODUCTION

Stroke is the most important cause of morbidity and long-term disability in Europe, and 40% of patients with stroke need active rehabilitation services (1). Regaining mobility is a primary goal of patients with stroke during rehabilitation, since it is a key factor in becoming independent in daily functioning. Predicting mobility (i.e. independent physical movement within the environment (2)), especially for the long-term, is essential to be able to inform patients and their families about the consequences of the stroke when a patient has to function in the community again.

Most studies on outcome prediction in a rehabilitation-based stroke population have focused on activities of daily living (ADL) (3–11). Important predictors of functional outcome were age (5–7, 9), stroke severity (6), motor impairment (3), sitting balance (4), urinary incontinence (9), co-morbidity (9) and disability at the start of the rehabilitation period (4–7, 9–11).

Only a few studies have been performed on prognostication of mobility-related outcomes after stroke. Mobility outcome, at 10 months post-stroke, was found to be best explained by self-efficacy, age and mobility at discharge from geriatric rehabilitation (12). In a community-based cohort, the ADL independency at admission to the stroke unit was the single predictor of walking ability at discharge (13). Age, sitting balance and bowel control were predictive factors for the walking item of the Barthel Index (BI) at discharge from the hospital (14). Sanchez-Blanco et al. (11) classified patients into 3 subgroups, viz., a motor, a motor-sensitive and a motor-sensitive with haemianopia group. This classification, plus pareses and age, determined ambulation at 6 months post-stroke. Another study (15) found that advanced age and severity of pareses were valid predictors of ambulation, also at 6 months post-stroke. Comfortable walking speed at 6 months post-stroke was best predicted by motor function, sitting balance and social support at 2 weeks post-stroke.

Unfortunately, the studies are not fully comparable, due to differences in definition and, with that, in measures used, timing post-stroke and a number of methodological shortcomings (16). Also, Meijer et al. (17) concluded, after reviewing the literature, that summarizing prognostic factors for ambulation and ADL was not feasible. They suggested that further research was needed on prognostication of stroke outcome in the subacute phase.

The aim of the present study was to derive a prognostic model for an inpatient rehabilitation cohort, in order to predict mobility outcome 1 year post-stroke.

METHODS

Design

Between April 2001 and April 2003 patients with stroke receiving inpatient rehabilitation were recruited for the Functional Prognosis after stroke study (i.e. FuPro-Stroke study). This prospective cohort study was

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conducted in 4 Dutch rehabilitation centres (see Acknowledgements). The medical ethics committees of University Medical Centre Utrecht and the participating rehabilitation centres approved the FuPro-Stroke study. All patients included gave their informed consent. A proxy gave informed consent if the patient could not communicate.

Subjects

All patients were included at the start of their inpatient rehabilitation in 1 of the 4 rehabilitation centres across the Netherlands. All patients had been hospitalised before admission to the rehabilitation centre. Inclusion criteria were: age over 18 years, first-ever stroke (cerebral infarctions or intra-cerebral haemorrhages) and a supratentorial lesion located on one side. Stroke was defined according to the World Health Organization (WHO) definition (18). Exclusion criteria were pre-stroke BI lower than 18 (0–20), insufficient Dutch language skills, and subarachnoid haemorrhages. Patients for whom the time between stroke onset and measurement was more than 100 days were excluded from analysis.

Dependent variables

The definition of mobility is equivocal, and can be given from different perspectives and in different terms (2). The used outcome measure for mobility was the Rivermead Mobility Index (RMI) (19). The RMI is a further development of the Rivermead Motor Assessment, consisting of 14 questions and 1 observation. The items are scored dichotomously 0–1 and were summated. Total scores range from 0 to 15 and a higher score reflects better mobility. The questions can be answered by patients or carers (19). It is a simple and short outcome measure to determine mobility. The RMI is valid and reliable (19, 20), responsive to change (21) in patients with stroke and its items cover a wide range of activities, from turning over in bed to running.

Independent variables

Independent variables were chosen on the basis of the results of previous studies and on clinical grounds. The following independent variables were included: sex, age, type of stroke, hemisphere, co-morbidity, living status, haemianopia, aphasia, inattention, functional status, urinary incontinence, sitting balance, motor function, cognition and time between stroke onset and the first measurement. An independent observer collected data concerning the type of stroke (infarctions or haemorrhages) and its location, presence of haemianopia, co-morbidity (the presence of cardiovascular and/or respiratory diseases, diabetic mellitus and co-morbidity of the locomotor system) and living status (living alone or not). Inattention was measured by the letter cancellation task (22) and was scored positive when the patient scored 2 omissions or more on one side, compared with the other side. The total score (0–20) of the activities of daily living (ADL) BI (23) was used to describe functional status. Urinary incontinence was assessed with the corresponding BI item. Although the item was originally scored on a 3-point scale (continent, occasional accident (maximum once a day), incontinent), the score was dichotomised for the present analyses (0 = continent, 1 = incontinent or occasional accident). The Trunk Control Test (TCT) is valid and reliable in stroke patients (24) and was used to assess sitting balance. The corresponding item was dichotomised: 0 for patients not able to sit independently, vs 1 for patients able to sit independently. The Motricity Index (MI) is a valid and reliable measure (24) and was used to determine motor function of the arm (MI arm) and the leg (MI leg). Scores ranged from 0 (no activity) to 33 (maximum muscle force) for each dimension. Cognitive status was assessed with the Mini Mental State Examination (MMSE) (25). Aphasia was defined with the Token Test (short form) (26) and the Utrechts Communicatie Onderzoek (UCO) (27). Patients scoring 9 errors or more on the Token Test and/or scoring less than 4 on the UCO were considered aphasic. Since only communicative patients completed the MMSE, a dichotomous variable for cognition was developed on the basis of a positive score on the MMSE score or on the existence of aphasia. The cognition variable was scored positive if MMSE $\leq$23 or patients were classified as aphasic.

Procedure

After admission to the rehabilitation centre (t0) and at one year (t1) post-stroke, patients were visited by a research assistant. Baseline values were obtained within 2 weeks after t0 by collecting data from medical charts, face-to-face interviews and physical and cognitive examination. For patients who could not communicate, information was gained by interviewing a member of the nursing staff.

At t1, patients were visited by a research assistant for an assessment at home or at the institution where they were staying. The RMI was completed and for patients who could not communicate, a proxy was interviewed. Most often this was the patients' spouse and occasionally a member of the nursing staff if the patient was institutionalised.

Data analysis

Data from all patients were entered into a computer database and analysed with the SPSS statistical package (version 12.0). Multiple linear regression analysis was used to predict RMI score. The data set was split non-randomly into a model-developing set and a cross-validation set, based on time of inclusion. The model-developing set, comprising the first 174 patients included (80%), was used to derive the prognostic model, whose validity could be tested in the cross-validation set, comprising the last 43 patients (20%) (28).

Univariate regression analysis of the model-developing set was used to select significant determinants ($p < 0.1$) for the subsequent development of the multivariate linear regression model. This selection, with a more liberal significance level, increased the sensitivity for selection of true predictors and limited the bias in the selected coefficients. These candidate determinants were tested for multicollinearity to prevent over-parametrization of the prediction model. The variables were cross-tabulated, and if the correlation coefficient was >0.7, the variable with the lowest correlation coefficient, in relation to the outcome measure, was omitted from the analysis (29). The remaining significant variables were used in a backward multivariate linear regression analysis. Collinearity diagnostics (i.e. eigenvalues, condition index) were applied for each variable to control for unstable estimates and make sure that the proportion of variance for a particular variable was unique and not due to other variables in the model. A condition index greater than 10 was interpreted as indicating the presence of collinearity (30). The final model was validated by calculating the explained variance in the cross-validation group. After cross validation the model was re-fitted in the total (model-developing + cross-validation) data-set. Each hypothesis was tested with a two-tailed analysis, using 0.05 as the level of significance.

RESULTS

At t0, 308 patients were included in the FuPro-Stroke study. After the patients with a subarachnoid haemorrhage had been excluded, 274 patients remained. At t1, 235 patients were interviewed. Seven patients had died within the first year after stroke, 12 patients had had a recurrent stroke, and were therefore excluded from follow-up, 17 patients refused participation and 3 could not be traced. Median time between stroke onset and t1 was 52.0 weeks (interquartile range = 51–53). Nine patients were excluded because the time interval between stroke onset and first measurement was more than 100 days. In addition, there were 9 missing values for co-morbidity, therefore, complete data-sets were available for 217 patients. Mean age was 58 years, and 65% were men. Mean time between stroke onset and t0 was 45 days (standard deviation (SD) = 16) (Table I). Treatment availability was more or less the same for all patients in our population and applied according to the Dutch stroke guidelines. All patients received multidisciplinary rehabilitation therapy consisting of physical and occupational therapy, speech–language pathology, psychology and therapeutic recreation for 5 days a week.

Table I. *Patient characteristics at admission (t0); total group, model-development group and cross-validation group*

	Total $n=217$	Model developing $n=174$	Cross-validation $n=43$
Gender (% female)	35	36	30
Mean (SD) age (years)	58 (11)	58 (11)	55 (11)
Living status (% living alone)	23	24	21
Co-morbidity† (% present)	79	79	80
Type of stroke (% haemorrhage)	17	17	16
Hemisphere (% right)	47	48	44
Mean time (SD) between stroke onset and t0 (days)	45 (16)	45 (16)	45 (14)
Haemianopia (% present)	19	20	14
Aphasia (% present)	30	31	26
Median (IQR) MMSE*	27 (3)	27 (4)	27 (3)
Cognition (% cognitive problems and/or aphasia)	42	44	30
Inattention (% present)*	35	37	29
Urinary incontinence (% present)	28	31	16
Median (IQR) Motricity Index (arm)	47 (65)	50 (63)	39 (67)
Median (IQR) Motricity Index (leg)	48 (38)	53 (38)	42 (43)
Sitting balance (% present)	84	85	81
Median (IQR) Barthel Index	13 (7)	13 (7)	14 (6)

MMSE = Mini Mental State Examination (0–30, $\leq$23 indicates cognitive problems); Aphasia was determined by the short form Token Test ($\geq$9 errors indicates presence of aphasia); Sitting balance was present when the score on the sitting item of the Trunk Control Test was 25; Urinary incontinence was present when the corresponding item on the Barthel Index was scored as 0 or 1. Inattention was defined as 2 omissions or more on one side, compared with the other side, in the letter cancellation task.
*$n=151$, 120, 32, respectively.
†Presence of cardiovascular and/or respiratory diseases, diabetic mellitus and co-morbidity of the locomotor system.

At t1, 2 patients (1%) were still in the rehabilitation centre and 9 (4%) were living in a nursing home. Thirty-eight patients (18%) could not communicate at t1 and, therefore, proxy ratings for the RMI were obtained from the spouse (97%) or the nursing staff (3%). In the complete data-set mean RMI score was 12.0 (SD = $\pm$3.1) at t1. Sixteen percent of the patients scored a maximum RMI score of 15. After data splitting on the basis of the time of inclusion, 174 patients (80%) were assigned to the model-developing set and 43 (20%) patients to the cross-validation set. Baseline characteristics of the patients included in both sets are illustrated in Table I.

Univariate analysis

Univariate analysis showed significant associations between, on the one hand, RMI at t1, and, on the other hand, age, cognition, type of stroke, inattention, co-morbidity, urinary incontinence, functional status (BI), sitting balance (TCT), motor function (MI arm, MI leg) and time between stroke onset and the moment of measurement at t0 in the model-developing set (Table II).

The BI, MI arm and MI leg scores showed high collinearity (Spearman's rank correlation coefficients ranging from 0.72 to 0.74). Because the BI showed the strongest association with the RMI score, the BI was used in the multivariate regression analysis.

Multivariate analysis

The backward linear regression analysis constructed a model with age, type of stroke, time between stroke onset and measurement, sitting balance and functional status as predictive factors (Table II). Collinearity diagnostics showed a high condition index of 18.7 for the type of stroke. This variable was therefore excluded from the final regression model. Functional status, sitting balance, time between stroke onset and measurement, and age were valid predictors in the final model ($Y = 10.75 + 0.30 \times BI + 2.65 \times$ sitting balance $- 0.04 \times$ days between stroke onset and measurement $- 0.05$*age). The explained variance of the model was 0.50 (adjusted $R^2 = 0.48$) in the model-developing sample. The found adjusted R^2 of the model in the cross-validation sample was 0.47, and 84% of the patients were correctly classified within $+/-2$ RMI-units (mean RMI = 12.4, 95% confidence interval (CI) = 11.8–13.0). After re-fitting the model in the total data-set, the mean value of the RMI was 12.1, with a 95% CI for mean of 11.8–12.4. Eighty-one percent of the patients were correctly classified within $+/-2$ RMI-units.

DISCUSSION

Mobility outcome was optimally predicted by functional status, sitting balance, time between stroke onset and first measurement, and age at admission to inpatient rehabilitation. It is important to note that more than two-thirds of these relatively young patients were not able to walk independently, according to the BI mobility item, suggesting that prognostication of mobility outcome was justified. The final model explained 48% of the variance of the outcome on RMI score at t1, which is comparable to other prognostic research. In a previous study, sitting balance, MI leg score and social support explained 49% of the variance in comfortable walking speed at 6 months

Table II. *Univariate and multivariate linear regression analysis: standardized Beta coefficients of independent variables assessed at admission for inpatient rehabilitation and Rivermead Mobility Index (RMI) score at 1 year post-stroke (n = 174)*

	Univariate analysis		Multivariate analysis		
Determinants	Standardized Beta	*p*-value	Standardized Beta	*p*-value	% explained variance
Gender (female)	−0.042	0.580			
Age*	−0.188	0.013	−0.177	0.001	3%
Living alone	−0.121	0.113			
Co-morbidity (present)*	−0.147	0.053			
Type of stroke (haemorrhage)*	0.176	0.020			
Hemisphere (right)	−0.052	0.499			
Mean time between stroke onset and admission (days)*	−0.247	0.001	−0.209	<0.001	4%
Haemianopia (present)	0.094	0.217			
Cognition (impaired cognition)*	−0.231	0.002			
Inattention (present) †	−0.277	0.002			
Urinary incontinence (present)*	−0.264	<0.001			
MI arm	0.450	<0.001			
MI leg	0.466	<0.001			
Sitting balance (present)*	0.540	<0.001	0.293	<0.001	8%
BI*	0.575	<0.001	0.437	<0.001	33%

*Included in the multivariate analysis. MI = Motricity Index (range 0–100); TCT = Trunk Control Test (range 0–100); TT = Token test, short form (range 0–20); BI = Barthel Index (range 0–20). The multivariate model included BI, sitting balance, time between stroke onset and measurement and age and explained 48% of the total variance.
†Inattention was not included in the multivariate analysis, because only patients without aphasia completed the letter cancellation task (n = 120).

post-stroke (15). For a smallest detectable difference of 2 points (31), the model was able to predict the scores with an accuracy of 81%. This underpins the robustness of found determinants. This model is slightly higher compared with another study in which 77% of the patients were correctly classified on the Functional Ambulation Categories (FAC) (11). To our knowledge, the present prospective study is the largest prognostic study aimed to forecast long-term outcome of mobility for patients admitted in a stroke rehabilitation ward.

The strongest predictor (33%) in our model was functional status (BI), which is in agreement with previously published studies evaluating functional outcome (6, 7, 9, 11). One study on mobility outcome showed that functional status (BI) at admission to the hospital was the single predictor for walking ability in a multivariate model (13). The strong predictive value of functional status for mobility outcome was expected, in view of the close interrelationship between BI and RMI (19, 20).

Sitting balance was another independent factor associated with RMI, suggesting that balance control is highly specific to control of mobility (20). This finding is in agreement with those of Duarte and colleagues (4), who showed that trunk balance while sitting is closely associated with gait velocity and walking distance. Similarly, Kwakkel et al. (15), showed that sitting balance in the first week post-stroke was an independent determinant for predicting comfortable walking speed at 6 months. Another study showed that balance, determined by the sit and reach test, explained 33% of the variance of Functional Independence Measure (FIM) mobility score at discharge (32). The present study shows that just assessing the sitting balance, as tested by 30 seconds of sitting unsupported following the TCT test, is an important predictor for outcome of mobility after stroke.

Time between stroke onset and measurement was a valid predictor in our study, suggesting that shorter intervals between stroke onset and admission are associated with better RMI scores at 1 year post-stroke. The average onset to admission interval in the present study was 45 days, which is comparable to other European studies (33), but seems longer compared to American studies (34). Our result seems to confirm previous studies, in which an earlier start of inpatient rehabilitation was found to be related to better outcomes in the longer term (7). Hypothetically, this relationship could be partialled out by correcting for differences in functional status at admission and other patient characteristics. However, in contrast to what might be expected, patients who had a longer onset to admission interval did not have a lower BI score at admission to inpatient rehabilitation ($r = -0.283$ vs partial correlation $r = -0.277$). Unfortunately, we were not able to include variables considering functional status and patient characteristics (i.e. co-morbidity and medical complications) during hospital stay. These variables might have had an influence on the time interval between stroke onset and admission.

According to other studies of functional outcome in a rehabilitation population (5–7, 9, 11, 33), age is also an independent factor. Previous prospective studies have shown that older age was negatively related to mobility outcome at discharge from the hospital (14) as well as to long-term outcome after stroke (11, 15). Age has also been found to be a valid long-term predictor of FIM mobility outcome in elderly stroke patients (12). In our study, age played a small but independent role in mobility outcome, which shows that even in this

relatively young stroke population, age affects the prognosis of recovery of mobility. Motor function was found to be a determinant for mobility outcome in stroke patients (35). In the present study MI was highly correlated with BI and therefore not included in the multivariate analysis. However, because of this high association and since BI is a predictor for mobility outcome, it is reasonable to assume that motor function might be a predictor for mobility outcome in this study as well.

Unfortunately, comparison between prognostic studies is often impeded by differences in selecting a uniform set of outcome measures for developing prediction models, as well as in the way they are defined. Secondly, determinants and outcomes are measured at different time intervals post-stroke, depending on the stroke population involved. Thirdly, most prognostic studies showed several methodological shortcomings (16). Only a few used multivariate analysis, calculated the explained variance of outcome, or validated the model. Due to a lack of validation, most derived prediction models probably overestimate the accuracy of prediction. In the present study, the regression model was validated in a non-random sample. Non-random splitting is a tougher test than random splitting, since random splitting leads to a data set that is the same apart from chance variation (28).

Although we explained a substantial part of the variance with our model, still half of the variation remains unexplained. Many variables were assessed, but for pragmatic reasons no other variables, such as RMI at t0, were assessed and included in the analysis. Also, factors such as post-discharge therapy and home exercise programs were not analysed in the present study. In addition, further investigation is needed to validate the present model in an early phase post stroke. Finally, it is important to note that the model is tested for a relatively young stroke population admitted in rehabilitation setting. Therefore, generalisation of the present model with respect to age might be limited. It should be noted, however, that the patients who dropped out and were not included the model development, were not significantly different from those who were included, except that the drop-outs showed more aphasia.

In the present study, the RMI was used as an outcome measure, which may be arbitrary. Although, 16% of the patients scored the maximum score of 15, this ceiling was judged as acceptable, since a ceiling effect higher than 20% is considered to be significant (36). In our opinion, the RMI is a useful measure covering a wide range of mobility items. Nevertheless, we encourage development of new outcome measures for mobility in chronic stroke without the presence of ceiling effects.

In conclusion, the present study shows that it is possible to derive a valid model, which includes predictors that are easy to assess and commonly collected in rehabilitation, and explains a substantial proportion of variation in long-term mobility outcome. In our opinion the model may serve as a guide to support clinicians in their stroke management to predict outcome of mobility at one year after stroke.

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REFERENCES

1. Hacke W, Kaste M, Bogousslavsky J, Brainin M, Chamorro A, Lees K, et al. European Stroke Initiative Recommendations for Stroke Management – update 2003. Cerebrovasc Dis 2003; 16: 311–337.
2. Bussmann JB, Stam HJ. Techniques for measurement and assessment of mobility in rehabilitation: a theoretical approach. Clin Rehabil 1998; 12: 455–464.
3. Chae J, Johnston M, Kim H, Zorowitz R. Admission motor impairment as a predictor of physical disability after stroke rehabilitation. Am J Phys Med Rehabil 1995; 74: 218–223.
4. Duarte E, Marco E, Muniesa JM, Belmonte R, Diaz P, Tejero M, et al. Trunk control test as a functional predictor in stroke patients. J Rehabil Med 2002; 34: 267–272.
5. Kelly PJ, Furie KL, Shafqat S, Rallis N, Chang Y, Stein J. Functional recovery following rehabilitation after hemorrhagic and ischemic stroke. Arch Phys Med Rehabil 2003; 84: 968–972.
6. Lin JH, Hsieh CL, Lo SK, Hsiao SF, Huang MH. Prediction of functional outcomes in stroke inpatients receiving rehabilitation. J Formos Med Assoc 2003; 102: 695–700.
7. Musicco M, Emberti L, Nappi G, Caltagirone C. Early and long-term outcome of rehabilitation in stroke patients: the role of patient characteristics, time of initiation, and duration of interventions. Arch Phys Med Rehabil 2003; 84: 551–558.
8. Paolucci S, Antonucci G, Grasso MG, Bragoni M, Coiro P, De Angelis D, et al. Functional outcome of ischemic and hemorrhagic stroke patients after inpatient rehabilitation: a matched comparison. Stroke 2003; 34: 2861–2865.
9. Pettersen R, Dahl T, Wyller TB. Prediction of long-term functional outcome after stroke rehabilitation. Clin Rehabil 2002; 16: 149–159.
10. Stineman MG, Maislin G, Fiedler RC, Granger CV. A prediction model for functional recovery in stroke. Stroke 1997; 28: 550–556.
11. Sanchez-Blanco I, Ochoa-Sangrador C, Lopez-Munain L, Izquierdo-Sanchez M, Fermoso-Garcia J. Predictive model of functional independence in stroke patients admitted to a rehabilitation programme. Clin Rehabil 1999; 13: 464–475.
12. Hellström K, Lindmark B, Wahlberg B, Fugl-Meyer AR. Self-efficacy in relation to impairments and activities of daily living disability in elderly patients with stroke: a prospective investigation. J Rehabil Med 2003; 35: 202–207.
13. Wandel A, Jørgensen HS, Nakayama H, Raaschou HO, Olsen TS. Prediction of walking function in stroke patients with initial lower extremity paralysis: the Copenhagen Stroke Study. Arch Phys Med Rehabil 2000; 81: 736–738.
14. Loewen SC, Anderson BA. Predictors of stroke outcome using objective measurement scales. Stroke 1990; 21: 78–81.
15. Kwakkel G, Mulder FV, Ooms AC. Het prediceren van loopvaardigheid na een beroerte: een prospectief cohortonderzoek. Nederlands Tijdschrift voor Geneeskunde 2004; 114: 2–8.
16. Kwakkel G, Wagenaar RC, Kollen BJ, Lankhorst GJ. Predicting disability in stroke–a critical review of the literature. Age Ageing 1996; 25: 479–489.

17. Meijer R, Ihnenfeldt DS, de Groot IJ, van Limbeek J, Vermeulen M, de Haan RJ. Prognostic factors for ambulation and activities of daily living in the subacute phase after stroke. A systematic review of the literature. Clin Rehabil 2003; 17: 119–129.
18. Stroke–1989. Recommendations on stroke prevention, diagnosis, and therapy. Report of the WHO Task Force on Stroke and other Cerebrovascular Disorders. Stroke 1989; 20: 1407–1431.
19. Collen FM, Wade DT, Robb GF, Bradshaw CM. The Rivermead Mobility Index: a further development of the Rivermead Motor Assessment. Int Disabil Stud 1991; 13: 50–54.
20. Hsieh CL, Hsueh IP, Mao HF. Validity and responsiveness of the rivermead mobility index in stroke patients. Scand J Rehabil Med 2000; 32: 140–142.
21. Hsueh IP, Wang CH, Sheu CF, Hsieh CL. Comparison of psychometric properties of three mobility measures for patients with stroke. Stroke 2003; 34: 1741–1745.
22. Lezak MD. Neuropsychological Assessment. Oxford: Oxford University Press; 1995.
23. Collin C, Wade DT, Davies S, Horne V. The Barthel ADL Index: a reliability study. Int Disabil Stud 1988; 10: 61–63.
24. Collin C, Wade D. Assessing motor impairment after stroke: a pilot reliability study. J Neurol Neurosurg Psychiatry 1990; 53: 576–579.
25. Folstein MF, Folstein SE, McHugh PR. "Mini-mental State". A pratical method for grading the cognitive state of patients for the clinician. J Psychiatrc Research 1975; 12: 189–198.
26. De-Renzi E, Vignolo LA. The Token Test: a sensitive test to detect receptive disturbances in aphasics. Brain 1962; 85: 665–678.
27. Pijfers EM, Vries LAd, Messing-Petersen H. The Utrecht Communication Observation (Het Utrechts Communicatie Onderzoek). Westervoort, Stichting Afasie Nederland; 1985.
28. Altman DG, Royston P. What do we mean by validating a prognostic model? Stat Med 2000; 19: 453–473.
29. Tabachnick BG, Fidell LS. Using multivariate statistics. New York: HarperCollins; 1996.
30. Belsey DA, Kuh E, Welsch RE. Regression diagnostics. New York: John Wiley and Sons; 1980.
31. Green J, Forster A, Young J. A test-retest reliability study of the Barthel Index, the Rivermead Mobility Index, the Nottingham Extended Activities of Daily Living Scale and the Frenchay Activities Index in stroke patients. Disabil Rehabil 2001; 23: 670–676.
32. Tsang YL, Mak MK. Sit-and-reach test can predict mobility of patients recovering from acute stroke. Arch Phys Med Rehabil 2004; 85: 94–98.
33. Paolucci S, Grasso MG, Antonucci G, Bragoni M, Troisi E, Morelli D, et al. Mobility status after inpatient stroke rehabilitation: 1-year follow-up and prognostic factors. Arch Phys Med Rehabil 2001; 82: 2–8.
34. Bode RK, Heinemann AW, Semik P, Mallinson T. Relative importance of rehabilitation therapy characteristics on functional outcomes for persons with stroke. Stroke 2004; 35: 2537–2542.
35. Kollen B, van de Port I, Lindeman E, Twisk J, Kwakkel G. Predicting improvement in gait after stroke: a longitudinal prospective study. Stroke 2005; 36: 2676–2680.
36. van der Putten JJ, Hobart JC, Freeman JA, Thompson AJ. Measuring change in disability after inpatient rehabilitation: comparison of the responsiveness of the Barthel index and the Functional Independence Measure. J Neurol Neurosurg Psychiatry 1999; 66: 480–484.