Susceptibility to Deterioration of Mobility Long-Term After Stroke
A Prospective Cohort Study

Ingrid G.L. van de Port, MSc; Gert Kwakkel, PhD; Iris van Wijk, MD; Eline Lindeman, MD, PhD

Background and Purpose—The aim of the present study was to identify clinical determinants able to predict which individuals are susceptible to deterioration of mobility from 1 to 3 years after stroke.

Methods—Prospective cohort study of stroke patients consecutively admitted for inpatient rehabilitation. A total of 205 relatively young, first-ever stroke patients were assessed at 1 and 3 years after stroke. Mobility status was determined by the Rivermead Mobility Index (RMI), and decline was defined as a deterioration of ≥2 points on the RMI. Univariate and multivariate logistic regression analyses were performed to identify prognostic factors for mobility decline. The discriminating ability of the model was determined using a receiver operating characteristic curve.

Results—A decline in mobility status was found in 21% of the patients. Inactivity and the presence of cognitive problems, fatigue, and depression at 1 year after stroke were significant predictors of mobility decline. The multivariate model showed a good fit (Hosmer–Lemeshow test \( P > 0.05 \)), and discriminating ability was good (area under the curve 0.79).

Conclusions—Mobility decline is an essential concern in chronic stroke patients, especially because it might lead to activities of daily living dependence and affects social reintegration. Early recognition of prognostic factors in patients at risk may guide clinicians to apply interventions aimed to prevent deterioration of mobility status in chronic stroke. (Stroke. 2006;37:167-171.)

Key Words: activities of daily living ■ cerebrovascular accident ■ locomotion ■ prognosis

Because decreased mobility is one of the major concerns for patients surviving a stroke, improving mobility is one of the main goals of stroke rehabilitation. Previously published studies suggest that mobility-related outcome improves after rehabilitation treatment.\(^1\)\(^-\)\(^4\) However, it remains unclear whether improvements made during rehabilitation can be sustained long term after stroke.\(^5\)\(^,\)\(^6\) The general view is that little recovery is to be expected >6 months after stroke.\(^7\)\(^,\)\(^8\) Unfortunately, the course of mobility status in the chronic stage (ie, beyond 6 months after stroke) has hardly been studied, and the results have been contradictory. Whereas some studies found that patients maintain their levels of functional status or even improve over time,\(^1\)\(^,\)\(^9\) others observed that patients show a gradual deterioration in functional status in this chronic poststroke stage.\(^5\)\(^,\)\(^10\) Kwakkel et al\(^9\) showed that patients, on average, maintained the functional gains they had made from 6 to 12 months after stroke onset. However, about one third of all patients with incomplete recovery showed either significant functional improvement or deterioration in comfortable walking speed. Apparently, the absence of a significant average change in a stroke population does not reflect the individual improvement or deterioration of patients.

Especially, deterioration of walking ability long term is regarded as a major problem, resulting in a loss of activities of daily living (ADL) independency and social isolation. A number of randomized studies have shown that mobility improves by therapeutic interventions aimed at improving gait in chronic stroke patients.\(^11\)\(^-\)\(^15\) Therefore, it is highly useful to identify those patients who are susceptible to long-term deterioration. However, to date, there have only been few reports in the literature on research to identify factors able to predict which patients will show significant change.\(^3\) Therefore, the purpose of the present study was to identify clinical determinants able to predict the individuals who are susceptible to deterioration in mobility from 1 to 3 years after stroke.

Materials and Methods

Subjects
Subjects were stroke patients included in the first week of inpatient rehabilitation in 4 main rehabilitation centers in the Netherlands to participate in the longitudinal functional prognosis after stroke study (FuPro-Stroke study). All subjects had been hospitalized before admission to the rehabilitation center. Inclusion criteria were: >18 years of age, first-ever stroke, and a supratentorial lesion located on the cerebral hemisphere.
1 side. Stroke was defined according to the World Health Organization definition. Exclusion criteria were a prestroke Barthel Index (BI) <18 (0 to 20) and insufficient command of Dutch.

**Dependent Variable**

Mobility was assessed by the Rivermead Mobility Index (RMI). The RMI is a simple and short outcome measure, consisting of 14 questions and 1 observation. It is valid and reliable, and responsive to change. Its items cover a wide range of activities, from turning over in bed to running. The items are scored dichotomously (0–1) and summed, with a higher score reflecting better mobility (0–15). The questions can be answered by patients or carers. We considered a decline of ≥2 points on the RMI as the 95% confidence limits of measurement error (ie, error threshold). The change score was dichotomized into 1 for “deterioration” (a decline of ≥2 points) and 0 for “improvement or no change” beyond the error threshold.”

**Independent Variables**

The independent variables used in this study were clustered into 4 domains: patient and stroke characteristics, physical factors, psychological/cognitive factors, and social factors. The patient and stroke characteristics included gender, age, level of education, type of stroke, hemisphere, aphasia, and inattention. The physical factors included motor function, ADL independence, and level of activity. Psychological and cognitive factors included cognitive status, depression, and fatigue. Social factors considered were living alone and social support.

Data were collected on the type of stroke (infarction or hemorrhage) and its location. Aphasia was defined using the Token Test (short version) and the Utterance Communication Observation (Utrecht Communicatie Onderzoek [UCO]). Patients scoring ≥9 errors on the Token Test or scoring <4 on the UCO were considered aphasic. Inattention was measured by the letter cancellation task and was scored positive when the patient had ≥2 omissions at 1 side compared with the other side.

The Motricity Index (MI) was used to determine the motor functions of arm (MI arm) and leg (MI leg). Scores range from 0 (no activity) to 33 (maximum muscle force) for each dimension, with a maximum total score of 100. Scores were dichotomized, and scores between 0 and 75 on the MI leg dimension or between 0 and 76 on the MI arm dimension indicated no optimal range of motion, whereas higher scores indicated optimal range of motion. Functional status was determined by the ADL BI. Total score (0–20) of the BI was dichotomized into “dependent” (BI<19 points) and “independent” (BI 19 to 20 points). The Frenchay Activities Index (FAI) was used to determine the level of activity. Total scores ranged from 0 to 45 and were dichotomized into 0 to 15 as inactive and 16 to 45 as moderately/highly active.

Cognitive status was assessed with the mini mental state examination (MMSE). Scores vary from 0 (severe cognitive problems) to 30 (no cognitive problems), and the MMSE was completed only by nonaphasic patients. Scores were dichotomized and cognitive problems were regarded as present when MMSE was ≤23. Depression was measured by the Center for Epidemiologic Studies-Depression (CES-D) and dichotomized into “nondepressed” (CES-D<16 points) and “depressed” (CES-D≥16 points). Fatigue was determined by the Fatigue Severity Scale (FSS). The FSS consists of 9 questions, and total scores range between 9 and 63. The mean score (total score/9) was dichotomized into “nonfatigued” (FSS<4 points) and “fatigued” (FSS≥4 points). Social support was determined by the shortened version of the Social Support List (SSL-12), which consists of 12 questions about the frequency of social support in different situations. Scores on individual items range from 1 to 4, with a maximum score of 48. The sum score on this scale was dichotomized into <25 for no or minimal social support and 25 to 48 for moderate to high social support.

**Procedure**

At 1 (t1) and 3 (t2) years after stroke, patients were visited by a trained research assistant for an assessment at home or at the institution where the patient resided. For noncommunicative patients, proxies were interviewed, usually the patients’ spouses. The medical ethics committees of University Medical Center Utrecht and the participating rehabilitation centers approved the FuPro-Stroke study. All patients included gave their informed consent, whereas a proxy gave informed consent if a patient was not communicative.

**Statistics**

Data were analyzed with the SPSS statistical package (version 12.0). Mobility scores at 1 and 3 years after stroke were compared by means of the Wilcoxon signed rank test. Univariate analyses were conducted by calculating odds ratios to identify statistically significant candidate factors relating to mobility decline. Variables with a P value <0.2 were selected for use in the multivariate analyses. A more liberal significance level increased the power for selecting true predictors and limited the bias in the selected coefficients. Subsequently, significant independent variables were used in a multivariate backward logistic regression analysis to predict mobility outcome. Only determinants with a significance level <0.1 were allowed into the final model. Goodness of fit of the multivariate logistic model was tested with the Hosmer–Lemeshow test, and a receiver operating characteristic (ROC) curve was used to test the predictive properties of the developed regression model. A two-tailed significance level of 0.05 was used.

**Results**

At 1 year after stroke, 264 patients were assessed. During follow-up, 13 patients died, 33 patients withdrew, and 13 patients were lost to follow-up (moved, residing outside the Netherlands). Baseline characteristics of the patients included at 3 years after stroke were not significantly different from those who had ended their participation in the study except for age, MMSE, and FAI (Table 1). At 3 years, 205 patients were assessed, and RMI data were available for 202 patients. Mean age at t1 was 57 years (SD=11), and 59% were men. Of the patients, 76% were living with a partner, 2% were still residing at a rehabilitation center, and 4% were institutionalized.

Mobility decline was found in 43 patients (21%), whereas 146 patients (72%) had maintained their mobility status, and 146 patients (72%) had maintained their mobility status, and

**TABLE 1. Patient Characteristics at 1 Year After Stroke for Patients Included and Not Included in the 3-Year Follow-Up Assessment**

<table>
<thead>
<tr>
<th>Patient Characteristic</th>
<th>Included (n=205)</th>
<th>Not Included (n=59)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender, % male</td>
<td>59</td>
<td>68</td>
</tr>
<tr>
<td>Age, % &gt;65*</td>
<td>25</td>
<td>39</td>
</tr>
<tr>
<td>Living alone, %</td>
<td>24</td>
<td>26</td>
</tr>
<tr>
<td>Hemispheric, % right</td>
<td>46</td>
<td>46</td>
</tr>
<tr>
<td>Type of stroke, % infarction</td>
<td>72</td>
<td>78</td>
</tr>
<tr>
<td>Aphasia, % present</td>
<td>18</td>
<td>25</td>
</tr>
<tr>
<td>MMSE, % ≤23*</td>
<td>11</td>
<td>26</td>
</tr>
<tr>
<td>Mileg, % impaired</td>
<td>59</td>
<td>71</td>
</tr>
<tr>
<td>BI, % dependent</td>
<td>39</td>
<td>44</td>
</tr>
<tr>
<td>CES-D, % depressed</td>
<td>30</td>
<td>39</td>
</tr>
<tr>
<td>FSS, % fatigued</td>
<td>68</td>
<td>73</td>
</tr>
<tr>
<td>FAL, % inactive*</td>
<td>32</td>
<td>45</td>
</tr>
</tbody>
</table>

*P<0.05 in χ² test for cross tabs. n = No. of subjects.
13 patients (7%) had improved between 1 and 3 years after stroke. RMI change scores ranged from −12 (decline) to +4 (improvement). The median RMI score at t1 and t2 was 13 (interquartile range 3). Ceiling effects were relatively high at t1 (20%) and t2 (14%) but were not considered to be significant. The Wilcoxon signed rank test showed a statistically significant decrease in RMI score between 1 year and 3 years after stroke (z = −4.58; P < 0.05). Five percent of the patients experienced a recurrent stroke, and 46% received physiotherapy during follow-up.

Univariate analysis showed statistically significant associations between mobility decline and motor function of the leg (Mleg), ADL independency (BI), level of activity (FAI), cognitive function (MMSE), depression (CES-D), fatigue (FSS), and living alone (P < 0.2; Table 2).

Multivariate logistic regression analysis showed that level of activity, cognitive problems, fatigue, and depression at 1 year after stroke were statistically significant predictors of mobility decline between 1 and 3 years after stroke (Table 2). The multivariate model showed a good fit (Hosmer–Lemeshow test P > 0.05). Discriminating ability of the model was good, as shown by the area under the ROC curve (0.8).35

Discussion

The present study shows that about one fifth of the chronic stroke victims deteriorated significantly in terms of mobility status between 1 and 3 years after stroke. Patients who had a poor level of activity, had cognitive problems, reported about fatigue, and had depressive feelings at 1 year after stroke were highly susceptible to deterioration of mobility in the next 2 years. To our best knowledge, the present study is the largest prospective cohort study to date to investigate long-term deterioration of mobility in chronic stroke patients.

Longitudinal studies on changes long term after stroke have thus far been scarce, and most studies have concentrated on ADL outcome and mean changes. However, mean changes do not reflect individual changes in patients. One study that focused on long-term individual changes in mobility, as measured by the RMI, suggested that 43% of the stroke patients deteriorated in terms of mobility status. Deterioration was defined as a decline of ≥1 point on the RMI, whereas in the present study, deterioration was defined as any change beyond the 95% limits of measurement error on RMI. Also, Paolucci et al included patients who were more severely impaired and used a follow-up period with the variable end point of 1 year after discharge, which restricts the comparability with our study.

Interestingly, our prediction model shows that mobility decline is most strongly associated with psychological and cognitive factors and not, as might be expected, with physical factors such as lower limb strength. These findings are in agreement with a number of prospective cohort studies. Zinn et al suggested that cognitive impairments attenuated instrumental ADL recovery. Depression has been found to be a significant factor in poor mobility and ADL outcome after stroke. Recognizing depression is particularly important for clinicians because about one third of all stroke patients experience depression. Another common symptom of stroke patients is poststroke fatigue. However, the impact of fatigue on poststroke recovery remains unclear in the

### TABLE 2. Univariate and Multivariate Analyses Using Decline of Mobility as Outcome Measure

<table>
<thead>
<tr>
<th>Independent Variables</th>
<th>Univariate Analysis (n=Variable)</th>
<th>Multivariate Analysis (n=152)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B (β Coefficient)</td>
<td>SE</td>
</tr>
<tr>
<td>Patient/stroke characteristics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age, &gt;65</td>
<td>0.14</td>
<td>0.39</td>
</tr>
<tr>
<td>Sex, female</td>
<td>−0.44</td>
<td>0.36</td>
</tr>
<tr>
<td>Type of stroke, infarction</td>
<td>−0.04</td>
<td>0.38</td>
</tr>
<tr>
<td>Education level, university</td>
<td>−0.59</td>
<td>0.48</td>
</tr>
<tr>
<td>Inattention</td>
<td>0.22</td>
<td>0.46</td>
</tr>
<tr>
<td>Physical factors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Motor function, impaired*</td>
<td>0.82</td>
<td>0.39</td>
</tr>
<tr>
<td>ADL, dependent*</td>
<td>0.66</td>
<td>0.35</td>
</tr>
<tr>
<td>Level of activity, inactive*</td>
<td>1.16</td>
<td>0.37</td>
</tr>
<tr>
<td>Psychological and cognitive factors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cognition, MMSE impaired*</td>
<td>1.01</td>
<td>0.54</td>
</tr>
<tr>
<td>Depression, present*</td>
<td>1.24</td>
<td>0.40</td>
</tr>
<tr>
<td>Fatigue, present*</td>
<td>1.19</td>
<td>0.57</td>
</tr>
<tr>
<td>Social factors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Living alone*</td>
<td>0.50</td>
<td>0.38</td>
</tr>
<tr>
<td>Social support, absent</td>
<td>−0.38</td>
<td>0.47</td>
</tr>
<tr>
<td>Constant, multivariate</td>
<td>−2.96</td>
<td></td>
</tr>
</tbody>
</table>

n = No. of subjects; SE = standard error of the estimate. *P < 0.2 in univariate analysis.
literature. It has been suggested that the presence of fatigue accounts for more functional limitations and predicts decreased functional independence, but prospective cohort studies have so far been lacking.

Our results suggest that the negative impact of depression and fatigue in stroke patients should not be underestimated. Not only are these variables associated with poor functional outcome and mobility, it is also important to note that this relationship is probably not unidirectional, suggesting that poor mobility itself will contribute to the vicious circle by reducing the patients' level of activity and increasing their feelings of fatigue and depression.

It is possible that factors such as medication intake and the use of health care services between 1 and 3 years after stroke might have influenced outcome. However, receiving physical therapy during follow-up was not statistically significantly related to deterioration in mobility in our population. Also, the occurrence of a recurrent stroke between 1 and 3 years after stroke was not statistically significantly related to mobility decline ($\chi^2; P<0.05$). Regarding the generalizability of our results, it is important to note that only patients were included who received inpatient rehabilitation in the first year after stroke. However, it is especially in this relatively young and moderately disabled population that a decline in mobility status will be of major concern. Therefore, deriving a model in this population is highly relevant and valuable. It should be noted that the patients who were not included in the study showed significantly more cognitive problems and were less active than those included (Table 1). Because these are risk factors, mobility might actually decline in even more chronic stroke patients than the 21% we identified.

Conclusion

We can conclude that about one fifth of stroke patients show a significant decline in mobility status in the longer term after their stroke. It is important to identify factors predicting a decline, such as depression and fatigue. Reducing the severity of these risk factors by providing pharmacological treatment or rehabilitation programs may lower the risk of mobility decline. Moreover, intensive physical training programs, aimed at improving walking competency of chronic stroke patients, have proved to increase mobility status.

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