Recovery of Functional Status After Stroke
A Postrehabilitation Follow-up Study

L. Ferrucci, MD, PhD; S. Bandinelli, MD; J.M. Guralnik, MD, PhD; M. Lamponi, RPT;
C. Bertini, RPT; M. Falchini, RPT; and A. Baroni, MD

**Background and Purpose:** Information on predictors of long-term change in functional capacity after a rehabilitation program in stroke patients is scant. This study describes the long-term evolution of self-reported functional ability after discharge from rehabilitation and its relation with age, level of neural impairment at discharge, and changes in neural impairment during follow-up.

**Methods:** Fifty patients (31 men and 19 women; mean±SD age, 66.0±9.9 years; range, 47–86 years) with a first unilateral stroke and no severe cognitive impairment were consecutively enrolled. Self-reported disability in activities of daily living and neural impairment measured by the Fugl-Meyer Scale were evaluated after discharge from a rehabilitation program and 3 and 6 months later.

**Results:** Functional disability was significantly reduced after 3 and 6 months. Attenuation of disability occurred mainly among those patients with more severe baseline neural impairment. In this group, patients aged ≥65 years were more disabled at baseline than younger individuals, but they had the same rate of improvement. In patients aged <65 years, changes in disability over time could be attributed to changes in neural function, whereas older patients’ functional recovery was greater than that expected from their improvement in neural impairment alone.

**Conclusions:** These results suggest that in stroke patients with severe neural damage further functional improvement occurs even after completion of a rehabilitation program. There is evidence that older patients may be more likely to employ compensatory strategies to overcome some of the neural impairment that remains after stroke. (*Stroke* 1993;24:200–205)

**Key Words** • neuronal damage • rehabilitation • stroke

Many studies have examined the improvement in symptoms caused by neurological damage and the functional recovery experienced by stroke patients after the acute event. The studies have suggested that recovery reaches its maximal degree within 6 months and that very little change takes place after this interval.1–6 These studies included mainly patients discharged from acute-care facilities and did not provide enough information on the course of disability after the completion of a long-term rehabilitation program.

In current clinical practice stroke survivors enter a rehabilitation program at variable intervals after the acute event. Although it has been suggested that the recovery pattern may change after discharge from rehabilitation, the evolution of disability after the completion of long-term rehabilitation has not been fully understood. Previous studies that have addressed the trajectory of functional ability after the completion of rehabilitation have several methodological limitations. Recovery has usually been assessed only by self-reports of the level of autonomy in performing activities of daily living (ADLs).7–11 and very few studies have objectively assessed the evolution of neural damage.8 No previous research has attempted to relate change in neural impairment over time with change in disability. Baseline functional ability was generally assessed in the hospital, and was compared with follow-up assessments done after patient discharge. An accurate assessment of disability is possible only after hospital discharge, when the patient in the home environment is confronted with the necessities of daily life.

Previous studies of the postrehabilitation period have also failed to consider the effect of age. Though age is not significantly associated with severity of motor function impairment immediately after stroke, the amount of functional recovery during rehabilitation is lower in older patients.7,12 The influence of age on the pattern of change after rehabilitation can be confounded by the fact that older patients start the postrehabilitation period with a lower functional score.

This article reports results from a postrehabilitation follow-up study of hemiplegic patients and had two related objectives: to describe the evolution of self-reported functional ability over the 6 months after discharge from a rehabilitation unit and to investigate the relation of self-reported functional ability with age, level of neuromotor impairment at discharge, and

---


This work was partially completed while L.F. was a Visiting Associate in the Epidemiology, Demography, and Biometry Program, National Institute on Aging.

Address for correspondence: J. Guralnik, MD, PhD, National Institute on Aging, 7201 Wisconsin Avenue, Gateway Building, Suite 3C309, Bethesda, MD 20892.

Received April 20, 1992; final revision received November 3, 1992; accepted November 3, 1992.
TABLE 1. Inclusion Criteria

| Completed stroke and no further progressive neurological symptomatology |
| No previous stroke |
| Single unilateral lesion confirmed by computed tomogram performed within 3 months after acute event |
| Medical and neurological status considered stable |
| Plateau in sensorimotor recovery as judged by rehabilitation team |
| No significant hearing or visual deficit |
| Score on Mini-Mental State Exam of ≥21 |

changes in neuromotor impairment after discharge. To sort out the independent effects of age and neural damage, the study included patients with a wide range of age and severity of neural impairment and evaluated them three times after the completion of rehabilitation.

Subjects and Methods

From June 1989 to May 1991, all patients in the rehabilitation unit of the INRCA Geriatric Department (Florence, Italy) were evaluated before their discharge as candidates for the study. Using standard inclusionary criteria (Table 1), 50 patients (31 men and 19 women; mean ± SD age, 66.0 ± 9.9 years, range 47–86 years) were consecutively enrolled. Twenty-three patients suffered from right and 27 from left hemiplegia, and 17 patients had aphasia. Informed consent was obtained from all patients or their relatives.

A baseline evaluation 2 weeks after discharge and two follow-up visits 3 and 6 months later were done in the patient’s home by a physical therapist who had not been treating that specific patient during his/her stay in the rehabilitation unit. Two patients died between the first and second follow-up visits. Two patients were not evaluated at the 3-month follow-up visit because of acute health problems.

Neural impairment was assessed using the Fugl-Meyer Scale, an instrument for the quantitative measurement in stroke patients of recovery in motor function of the upper and lower extremities, balance, sensation, joint range of motion, and pain.10,13–15 A separate score for each subdomain and a global score were expressed as percentage of the maximum obtainable score. Gross mobility and walking performance were assessed by the Lindmark Motor Assessment Chart;16 a global score obtained by summing the scores of each single item, as suggested by the authors, was used in the analysis. Cognitive status was estimated by the Mini-Mental State Exam.17 The line bisection test18 was used to investigate neglect. Three lines 20, 40, and 60 cm long were used, and a summary index was obtained by summing the deviations from the center of each line expressed as percentage of the total length. The level of self-reported functional disability was estimated using the Barthel Index for ADLs,19 an instrument particularly useful as an outcome measure in follow-up studies of stroke patients,20 and the Lawton-Brody Scale for instrumental activities of daily living (IADLs).21 The severity of aphasia was estimated using the comprehension and expression indexes from the Boston Aphasia Examination protocol.22 For all these instruments, except the line bisection test and the Lawton-Brody Scale, a higher score indicates a higher level of functioning. Severity of aphasia and self-reported disability in IADLs were assessed only at the baseline examination and at the 6-month follow-up visit.

Internal consistency of the scales used in the study was estimated by computing Cronbach’s alpha statistics23,24 on the baseline data. The relation of age and level of neural impairment at baseline with the time from the acute event to admission to the study was analyzed by factorial analysis of variance.

For each variable, change over time was tested using a longitudinal random-effects model and employing the approach described by Jennrich and Schluchter.25 Random-effects models were also used to test the effects of age, level of neural impairment at baseline, and evolution of the neural impairment on changes over time in score on the Barthel Index. In these models, age and neural impairment at baseline were considered as fixed effects and the progression of neural status as a time-dependent covariate. A scheme of coding that considered two age groups (≤65 versus >65 years) and two levels of neural impairment at baseline (Fugl-Meyer Scale score ≤50th percentile versus >50th percentile) was used. These models were fitted to the data using the program BMESP, which can handle missing or censored visits via the EM algorithm.26 A within-person covariance structure assuming a constant correlation between observations (compound symmetry) was employed.

In the statistical evaluation of the association of both fixed and time-dependent covariates with the dependent variable (change in score on the Barthel Index over time), these covariates were entered into the model under the null hypothesis that they could be left out of the model without any significant change in prediction of the dependent variable. This hypothesis was tested by a Wald-type $\chi^2$ statistic.26 The $\chi^2$ values reported in the figures are also Wald-type $\chi^2$ statistics.

Results

The mean ± SD time from stroke to admission to the rehabilitation unit was 48.9 ± 37.7 (range 10–167) days, and the mean ± SD time of stay in the rehabilitation unit was 94.2 ± 36.4 (range 22–183) days; the time from the acute event to admission into the study was 143.0 ± 51.9 (range 45–287) days. In a factorial analysis of variance, none of these times was found to be significantly associated with age or level of neural impairment at baseline.

The Fugl-Meyer, Lawton-Brody, and Barthel instruments were highly reliable, with Cronbach’s alpha values of 0.91, 0.87, and 0.88, respectively.

Self-reported disability in ADLs, neural impairment measured by the Fugl-Meyer Scale, performance in mobility tasks, and level of communication in aphasic patients improved significantly during follow-up while self-reported functional ability in IADLs and scores on the Mini-Mental State Exam and line bisection test remained unchanged (Figures 1 and 2).

Evaluation of the subdomain scores of the Fugl-Meyer Scale (Figure 3) shows that the improvement occurred in motor scores, balance, and passive mobility score for the upper extremity, while sensation and passive mobility score for the lower extremity remained stable over time. In more than 95% of the cases, improvement in volitional movement consisted of
changes from a score of 1 to a score of 2 (qualitative improvement of a movement that was present at a previous assessment).

The effect of age and level of neural impairment at baseline on change in mean level of disability in ADLs was studied by introducing these two variables as fixed covariates in a random-effects model testing change in score of the Barthel Index over time. Table 2 shows the results of this analysis. Significance of the time effect indicates that score on the Barthel Index changes over time and that this change is independent of the effects of other covariates in the model. Significance of the age and baseline Fugl-Meyer score effects indicates that, independently of time, score on the Barthel Index differs in old and young patients and in patients with high and low Fugl-Meyer scores at baseline. Finally, the interaction terms time×baseline Fugl-Meyer score and time×age test the null hypothesis that the rate of change over time is not influenced by the level of neural impairment at baseline and by age. Only the time×baseline Fugl-Meyer score term was significant, indicating that the level of neural impairment at baseline, but not age, was a significant predictor of change over time of disability in ADLs.

To further investigate these results, analyses were done separately after stratification for age and baseline Fugl-Meyer score. Figure 4 illustrates the mean Barthel Index and Fugl-Meyer scores at baseline and at each follow-up visit for these four strata. Change over time in the Barthel Index score was analyzed in separate models for each stratum. For both age groups, mean score on the Barthel Index increased significantly during

---

**Figure 1.** Graphs of mean±SEM scores on activities of daily living (ADLs) and instrumental activities of daily living (IADLs) and percentages of maximum neuromuscular function and mobility at baseline and at follow-up visits after stroke rehabilitation. Score of Fugl-Meyer Scale is expressed as percent of maximum obtainable score to obtain the same range of values as Barthel Index.

**Figure 2.** Graphs of mean±SEM scores on Mini-Mental State Exam, line bisection test, and indexes of communication at baseline and at follow-up visits after stroke rehabilitation. Values of communication indexes are calculated only for the 17 patients with a diagnosis of aphasia at baseline.
follow-up only in subjects who had more severe neural limitations at baseline (baseline Fugl-Meyer score ≤124 and age <65 years: \( p=0.009 \); baseline Fugl-Meyer score ≤124 and age ≥65 years: \( p=0.001 \)) while it did not change significantly in the less impaired patients (baseline Fugl-Meyer score >124 and age <65 years: \( p=0.439 \); baseline Fugl-Meyer score >124 and age ≥65 years: \( p=0.082 \)).

To verify whether changes in functional disability were related to changes in neural impairment, the Fugl-Meyer scores measured over time were inserted as time-dependent covariates in models testing the change in Barthel Index score. These models were limited to the patients with severe neural impairment at baseline because they were the only groups showing significant change in score on the Barthel Index over time. In both models (Table 3), change in the Fugl-Meyer score was significantly associated with change in the Barthel Index score. In these models, if neural impairment and functional disability evolve in a parallel way, after adjusting for change in the Fugl-Meyer score, the variable time would no longer be a significant predictor of the Barthel Index score. In the younger group the time effect was not significant, indicating that the change in score on the Barthel Index was entirely explained by changes in neural impairment. In the older group, significance of the time effect indicates that there were changes in the Barthel Index score that were not entirely explained by changes in the Fugl-Meyer score.

Both Figure 4 and Table 3 provide evidence that the relation of changes in the Fugl-Meyer score to changes in the Barthel Index score differed in the two age groups. To test this, a model was constructed including both age groups and incorporating age and age×time terms as independent variables. In this model (not shown), the age×time interaction was significant, indicating that, regarding the ability of change in the Fugl-Meyer score to explain changes in disability, the two age groups are significantly different.

**Discussion**

In this study, stroke patients with severe neural impairment who were judged to have received the maximum benefit from rehabilitation were shown to improve in functional ability in ADLs after the completion of rehabilitation. This improvement was accompanied by a reduction of the neural impairment measured by the Fugl-Meyer Scale, which consisted mainly of qualitative improvements in volitional movements.

These findings were somewhat unexpected because previous studies have suggested that the reorganization of neurological function occurs within 3–6 months after stroke and that changes beyond this period are negligible.\(^{1,5,6,27,28}\) There are, however, several possible explanations for the discrepancy between these studies and the results presented here.

Several studies evaluated patients discharged directly from an acute-care hospital or patients who received physical therapy 2 or 3 times per week for short periods.\(^{1,29}\) In our program, at various times after the acute event patients received intensive physical and occupational therapy every day during a long period of

**TABLE 2. Longitudinal Random-Effects Model Testing Effect of Age and Baseline Score on Fugl-Meyer Scale on Change in Score on Barthel Index After Stroke Rehabilitation in 50 Patients**

<table>
<thead>
<tr>
<th>Independent variable</th>
<th>( \chi^2 )</th>
<th>( p )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td>23.03</td>
<td>0.0001</td>
</tr>
<tr>
<td>Age (&lt;65 vs. ≥65 yrs)</td>
<td>40.05</td>
<td>0.0001</td>
</tr>
<tr>
<td>Baseline Fugl-Meyer score (≤124 vs. &gt;124)</td>
<td>12.60</td>
<td>0.0001</td>
</tr>
<tr>
<td>Time×baseline Fugl-Meyer score</td>
<td>6.02</td>
<td>0.049</td>
</tr>
<tr>
<td>Time×age</td>
<td>2.80</td>
<td>0.247</td>
</tr>
</tbody>
</table>

**FIGURE 3.** Graphs of mean±SEM scores on different subdomains of Fugl-Meyer Scale at baseline and at follow-up visits after stroke rehabilitation. To increase comparability, scores are expressed as percent of maximum obtainable score in that subdomain. ROM, range of motion.
residence in an intramural program. Moreover, the study was restricted to patients affected by a first, single, unilateral lesion, without cognitive impairment, who experienced significant damage from their stroke that was still present at the time of admission to the rehabilitation program. Our study was limited to those patients most likely to improve. These exclusion criteria have not been employed in most stroke follow-up studies\(^1,27,28\) and may limit their comparability to our study. Lehmann et al\(^11\) and Anderson et al\(^30\) have also shown that intensive rehabilitation programs can improve the level of functional ability in stroke patients beyond the 6 months after the acute event. Similar results have been published by Davidoff et al\(^31\) who studied the long-term effect of rehabilitation, and by Tangeman et al\(^32\) who studied stroke patients who received a rehabilitative intervention 1 year after the acute event.

This study demonstrates several important findings concerning the effect of age. The extent of improvement in functional status was found to be independent of age. This is evident in Figure 4, which shows similar slopes of change in mean score on the Barthel Index in the two age groups, and in Table 2, in which the time\(\times\)age interaction in the model predicting score on the Barthel Index is not significant. However, age was an important effect modifier, both cross-sectionally and longitudinally, of the relation between neural impairment and disability. In patients with a baseline Fugl-Meyer score of \(\leq 124\), the level of neural impairment was similar in the two age groups but self-reported disability was substantially different, with older people reporting more disability.

A strong correlation between neuromotor impairment and functional disability in ADLs has been reported in the literature.\(^33\) However, two distinct factors contribute to functional recovery in stroke patients: neurological recovery and the patient's capacity to function in his/her environment through adaptation.\(^8,9,10,34\) In this study, a recovery from disability that was greater than the recovery expected given the changes observed in neural impairment was evident only in the older group. In the younger group, all the change over time in the Barthel Index score was "explained" by the change in the Fugl-Meyer score, but in the older group the mean value of both variables increased independently over time.

There are two important areas in need of further study that are relevant to understanding the relation of neurological function and disability: the role played by alternative strategies and the influence of comorbidity. Although a role for "compensatory strategies" is strongly suggested by this and other studies,\(^8,9,10,34\) this issue has not been extensively addressed. To study compensatory strategies, which can be physiological, physical, behavioral, environmental, psychological, and social, both precise definitions and specific assessment instruments need to be developed. Future research should be carried out to evaluate the impact on recovery of these strategies, with the eventual goal of designing interventions aimed at promoting their use.

**TABLE 3. Longitudinal Random-Effects Models Testing Effect of Time-Dependent Fugl-Meyer Score on Change in Barthel Index Score in Patients With Severe Neural Impairment at Baseline**

<table>
<thead>
<tr>
<th>Independent variable</th>
<th>(\chi^2)</th>
<th>(p)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;65 years ((n=13))</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time</td>
<td>0.76</td>
<td>0.682</td>
</tr>
<tr>
<td>Fugl-Meyer score</td>
<td>4.89</td>
<td>0.027</td>
</tr>
<tr>
<td>(\geq 65) yrs ((n=12))</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time</td>
<td>6.57</td>
<td>0.037</td>
</tr>
<tr>
<td>Fugl-Meyer score</td>
<td>3.86</td>
<td>0.049</td>
</tr>
</tbody>
</table>

**FIGURE 4.** Graphs of mean \(\pm\)SEM score on Barthel Index (●) and percent of maximum obtainable score on Fugl-Meyer Scale (○) at baseline and at follow-up visits after stroke rehabilitation. Results are stratified by age and level of neural impairment at baseline.
Although in younger patients the presence of disability is generally caused by a single, identifiable condition, a decline in function in older adults is often the result of multiple impairments related to the presence of comorbid conditions and their interaction. Because the Fugl-Meyer Scale has been specifically constructed to capture the severity of neural impairments related to stroke, it does not consider the presence and severity of impairment in other physiological systems. Further research on the relation between disease-specific impairments and disability in ADLs that takes into account the effects of comorbidity is needed to comprehensively evaluate the role of neural impairment on disability in older persons.

In conclusion, this study has demonstrated a number of previously unreported findings related to stroke recovery. These findings were made possible only because both neurological function and disability were measured with separate instruments. Further research on stroke recovery, especially when aimed at understanding the multiple factors that may influence recovery in older persons, should use this approach.

References
L Ferrucci, S Bandinelli, J M Guralnik, M Lamponi, C Bertini, M Falchini and A Baroni

Stroke. 1993;24:200-205
doi: 10.1161/01.STR.24.2.200

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://stroke.ahajournals.org/content/24/2/200