Long-Term Functional Recovery After First Ischemic Stroke
The Northern Manhattan Study

Mandip S. Dhamoon, MD, MPH; Yeseon Park Moon, MS; Myunghee C. Paik, PhD; Bernadette Boden-Albala, DrPH; Tatjana Rundek, MD, PhD; Ralph L. Sacco, MD, MS; Mitchell S.V. Elkind, MD, MS

Background and Purpose—Several factors predict functional status after stroke, but most studies have included hospitalized patients with limited follow-up. We hypothesized that patients with ischemic stroke experience functional decline over 5 years independent of recurrent stroke and other risk factors.

Methods—In the population-based Northern Manhattan Study, patients ≥40 years of age with incident ischemic stroke were prospectively followed using the Barthel Index at 6 months and annually to 5 years. Baseline stroke severity was categorized as mild (National Institutes of Health Stroke Scale <6), moderate (6 to 13), and severe (≥14). Follow-up was censored at death, recurrent stroke, or myocardial infarction. Generalized Estimating Equations provided ORs and 95% CIs for predictors of favorable (Barthel Index ≥95) versus unfavorable (Barthel Index <95) functional status after adjusting for demographic and medical risk factors.

Results—Of 525 patients, mean age was 68.6 ± 12.4 years, 45.5% were male, 54.7% Hispanic, 54.7% had Medicaid/no insurance, and 35.1% had moderate stroke. The proportion with Barthel Index ≥95 declined over time (OR, 0.91; 95% CI, 0.84 to 0.99). Changes in Barthel Index by insurance status were confirmed by a significant interaction term (β for interaction = −0.167, P = 0.034); those with Medicaid/no insurance declined (OR, 0.84; P = 0.003), whereas those with Medicare/private insurance did not (OR, 0.99; P = 0.92).

Conclusions—The proportion of patients with functional independence after stroke declines annually for up to 5 years, and these effects are greatest for those with Medicaid or no health insurance. This decline is independent of age, stroke severity, and other predictors of functional decline and occurs even among those without recurrent stroke or myocardial infarction. (Stroke. 2009;40:2805-2811.)

Key Words: disability ■ recovery ■ stroke

StROKE is the leading cause of serious, long-term disability in the United States. Considering the staggering prevalence of stroke, the burden of poststroke disability is of primary public health importance. Prior research on the natural history of disability after stroke has shown varying degrees of functional recovery within 6 to 12 months. Long-term functional outcomes are less clear, however.

Previous studies have identified demographic and stroke-specific characteristics that are associated with functional recovery after stroke. However, most of these studies have included only hospitalized patients with limited follow-up, and few population-based studies have examined predictors of functional status with long-term follow-up. Furthermore, the effect of socioeconomic status on functional status after stroke has not been examined over the long term.

We sought, in a prospective, population-based, multiethnic, urban stroke cohort study, to determine the long-term natural history and predictors of functional status among participants who experienced a first ischemic stroke. We hypothesized that patients with ischemic stroke experience functional decline over 5 years independent of recurrent stroke and other risk factors.

Subjects and Methods
The Northern Manhattan Study includes a population-based incident ischemic stroke follow-up study designed to determine predictors of stroke recurrence and prognosis in a multiethnic, urban population, as previously described. The race–ethnic mixture of the northern Manhattan community at the time of the study consisted of 63% Hispanic, 20% black, and 15% white residents.

Selection of the Northern Manhattan Study Cohort
The methods of patient identification and enrollment have been described in previous publications. Briefly, patients with ische-
mic stroke were enrolled if they (1) were diagnosed with a first stroke; (2) were age ≥40 years; and (3) resided in northern Manhattan for ≥3 months in a household with a telephone. Northern Manhattan Study was limited to ischemic stroke to restrict cases to a more homogeneous population and limit the underlying pathophys-ologies. Case ascertainment occurred between July 1993 and June 1996, and assessments were completed in August 2001. Over 80% of participants who were not hospitalized at Columbia University Medical Center, only those who had an initial evaluation within 20 days of their first stroke were included in analyses involving the surveillance of admissions to those hospitals and through agreements with local physicians. Approximately 5% of participants who incident ischemic stroke in northern Manhattan were not hospitalized and were also included. Evaluation of patients was performed at the hospital; those patients either not hospitalized or hospitalized elsewhere were evaluated in the outpatient research clinic. Of the participants who were not hospitalized at Columbia University Medical Center, only those who had an initial evaluation within 20 days of their first stroke were included in analyses involving the National Institutes of Health Stroke Scale. The study was approved by the Columbia University Medical Center Institutional Review Board. All participants gave consent directly or through a surrogate when appropriate.

**Index Evaluation of Subjects**

Data were collected through interviews by trained research assistants, and physical and neurological examinations were conducted by study neurologists, as previously described. Assessments were conducted in English or Spanish depending on the primary language of the participant. Race–ethnicity was based on self-identification. Standardized questions were adapted from the Behavioral Risk Factor Surveillance System20 by the Centers for Disease Control and Prevention regarding the following conditions: hypertension, dia- betes mellitus (DM), hypercholesterolemia, peripheral vascular disease, transient ischemic attack, cigarette smoking, and cardiac conditions such as myocardial infarction (MI), coronary artery disease, angina, congestive heart failure, atrial fibrillation, or arrhythmias, and valvular heart disease. Hypertension was defined as a systolic blood pressure recording ≥160 mm Hg or a diastolic blood pressure recording ≥95 mm Hg (based on the average of 2 blood pressure measurements) or the patient’s self-report of a history of hypertension or antihypertensive use. DM was defined by a fasting blood glucose level ≥126 mg/dL, the participant’s self-report of such a history, or insulin or oral hypoglycemic use. Presence or absence of urinary incontinence within 7 to 10 days of the index stroke was determined. Presence or absence of depressed mood in the week before stroke was assessed at enrollment. Physical activity was assessed using a questionnaire adapted from the National Health Interview Survey of the National Center for Health Statistics and classified as light–moderate and heavy, as previously described.

Stroke severity was assessed using the National Institutes of Health Stroke Scale score derived from a standardized neurological examination and was categorized into mild (<6), moderate (6 to 13), and severe (≥14). This categorization was based on previous analyses of stroke severity in relation to stroke outcome from our population and a clinical trial.21,22 Stroke diagnostic evaluation included CT and/or MRI of the brain, ultrasound evaluation and/or MR angiography of the extracranial and intracranial cerebral vessels, and transesophageal echocardiogram as appropriate. A consensus of stroke neurologists assessed stroke subtype using modified Stroke Data Bank criteria and all available information as described in a previous publication. Stroke neurologists also determined brain side of index stroke, presence of aphasia, and parietal lobe dysfunction including neglect.

**Follow-Up and Outcomes Assessment**

Follow-up evaluations were conducted at 6 months and then annually for 5 years. Evaluations were conducted at the medical center or by telephone interaction with the patient, family member, or caregiver. There was also a telephone assessment at 1.5 years. Information on vital status, functional status as measured by the Barthel Index (BI), and intercurrent symptoms, illness, or hospitalization was collected. Previous research has demonstrated the reliability of phone assess-ments of functional status using the BI.23 In-person assessments included interviews and assessment of functional status as well as measurement of vital signs, physical examination, and neurological examination.

Patients unable or unwilling to come to the medical center were visited by a member of the research staff, and the evaluation was conducted at home or in an alternative place of residence (eg, nursing home). An ongoing surveillance system of admissions to the Columbia University Medical Center and other local hospitals, described in a previous publication,16 was also used to identify study participants who experienced recurrent stroke, MI, hospitalization, or death. When available, medical records were reviewed for all outcome events, including death. All outcome events were initially reviewed by a specially trained research assistant, and events were then adjudicated by study neurologists or cardiologists, as appropriate.

**Statistical Analyses**

Statistical analyses were conducted using SAS Version 9.1.3 (SAS Institute, Cary, NC). For descriptive purposes, means were calculated for continuous variables and proportions for categorical variables. Follow-up was censored at the time of death, recurrent stroke, or MI because of the effect of these events on functional status. We used Generalized Estimating Equations to assess the relationship between several predictor variables, including time of follow-up at regular intervals, with functional outcome. The advantage of Generalized Estimating Equations is that this method accounts for within-subject correlation and produces unbiased and more efficient regression estimates in studies that have a longitudinal, repeated-measures design.24 Generalized Estimating Equations with binary outcome and logistic link function provided parameter estimates from which ORs and 95% CIs were calculated for predictors of favorable (BI ≥95) versus unfavorable (BI <95) functional status after adjusting for demographic (age, sex, race/ethnicity, education level, marital status, insurance status) and medical (hypertension, coronary artery disease or MI, DM, hypercholesterolemia, smoking, physical activity) risk factors as well as stroke characteristics known to be associated with functional recovery in previous studies (initial stroke severity, depressed mood before stroke, presence or absence of aphasia, presence of parietal lobe dysfunction including neglect, side of stroke, and presence of urinary incontinence). Insurance status was characterized as Medicare/private insurance versus Medicaid/no insurance. Multivariate models were constructed in a backward stepwise manner using those variables that were significant at P<0.10. In secondary analyses, we evaluated predictors for BI ≥60 versus <60.

Subgroup analysis was performed in those who had BI ≥95 at 6 months to determine the natural history and predictors of functional status in those deemed “recovered” after the acute phase of recovery. The interaction between time of the follow-up assessment and insurance status was included in multivariate regression models to assess whether the change in functional status over time differed by insurance status. After testing for interaction with insurance, the effect of follow-up time on functional status was also stratified by type of insurance.

Time of follow-up assessment was analyzed both continuously and discretely (at 1-, 1.5-, 2-, 3-, 4-, and 5-year time points with 0.5 year as the reference). The analysis of discrete time points did not assume any particular functional form, whereas the continuous model assumed a linear time trend. Using the model with discrete time points, we tested whether the trend was linear. In addition, in the continuous model, appropriateness of linearity was determined by testing whether the quadratic term was significantly different from zero.

To explore whether there was a significant decrement in functional status at a single time point, a change point, maximum likelihood estimates of the change point were obtained. To assess whether differential length of follow-up was related to functional status, which would have been a source of bias, a series of logistic regression models was fitted for each time point using an indicator of
whether each subject dropped out after each follow-up time point as the outcome and BI ≥95 and the same covariates in our final model as the predictors.

Results

There were 655 patients enrolled in the Northern Manhattan Study stroke incidence and follow-up study. No follow-up functional data were available for participants who died within 6 months (n=83) and for those who died between 6 months and 1 year (n=14). Five participants died after 1 year, but before functional data were collected. Twenty-four participants had recurrent stroke before the first functional assessment and were excluded from analysis. There were no functional data and no indication of death for 4 participants, who were categorized as lost to follow-up. Five hundred twenty-five patients were thus available for this analysis. In addition, during follow-up, 84 participants had recurrent stroke or MI, and there were 133 deaths. Table 1 lists baseline and demographic information for study participants.

There was an annual decline in the proportion of patients with BI ≥95 in an unadjusted regression model considering time to follow-up assessment as a continuous variable (OR per year after stroke, 0.96; 95% CI, 0.92 to 1.01). When adjusted for demographic variables, the annual decline was significant (adjusted OR, 0.94; 95% CI, 0.89 to 1.00) and did not change further when adjusted for demographic variables and medical risk factors (adjusted OR, 0.94; 95% CI, 0.88 to 0.99). Further adjusting for stroke characteristics such as stroke severity, neglect, side of stroke, and urinary incontinence led to a slightly more pronounced decline (adjusted OR per year after stroke, 0.91; 95% CI, 0.84 to 0.99). Results for the cutoff of BI ≥60 showed more marked declines; an unadjusted model showed OR of 0.93 (95% CI, 0.87 to 0.98), and models adjusted for demographic variables (adjusted OR, 0.90; 95% CI, 0.84 to 0.96) and demographics and medical risk factors (adjusted OR, 0.89; 95% CI, 0.83 to 0.96) showed that with every year of follow-up, participants were less likely to have BI ≥60. Table 2 reports the fully adjusted results.

In subgroup analysis for those participants who had BI ≥95 at 6 months (n=245), there was still a significant annual decline in the proportion with BI ≥95 over follow-up (unadjusted OR per year, 0.81; P<0.0001), and there was little change when adjusted for demographic variables (adjusted OR, 0.79; P<0.0001) and in the fully adjusted model (adjusted OR per year, 0.76; 95% CI, 0.65 to 0.89; Table 3).

Changes in BI over time differed significantly by insurance status (β for interaction = −0.167, P=0.034) with a decline in BI over time for those with Medicaid/no insurance (adjusted OR, 0.84; 95% CI, 0.75 to 0.94; P=0.003) but no definite decline among those with Medicare/private insurance (adjusted OR, 0.99; 95% CI, 0.90 to 1.11; P=0.92). No other 2-way interactions between time to follow-up and other variables were significant. Figures 1 and 2 depict functional status stratified by insurance status, unadjusted for other risk factors.

In the final regression model, time was treated as a continuous variable in linear form because there was no evidence that an alternative model better fit the data (lack of linearity χ² test: df=4, P=0.65).

| Table 1. Baseline Characteristics of the Study Population* |
|-----------------|-------------|
| No. of participants (n)† | 525 |
| Demographics | |
| Age, mean (SD), years | 68.6 (12.4) |
| Male, no. (%) | 239 (45.5) |
| Received at least high school education, no. (%) (n=513) | 169 (32.9) |
| Marital status, no. (%) (n=517) | 178 (34.4) |
| Non-Hispanic white, no. (%) | 85 (16.2) |
| Non-Hispanic black, no. (%) | 141 (26.9) |
| Hispanic, no. (%) | 287 (54.7) |
| Other race, no. (%) | 12 (2.3) |
| Insured with Medicaid or uninsured, no. (%) | 279 (54.7) |
| Insured with Medicare or private insurance, no. (%) | 231 (45.3) |
| Risk factors, no. (%) (n=524) | |
| History of MI | 87 (16.6) |
| History of coronary artery disease | 156 (29.7) |
| History of atrial fibrillation | 51 (9.7) |
| History of peripheral arterial disease | 114 (21.8) |
| Current smoking | 113 (21.6) |
| Past smoking | 177 (33.8) |
| DM | 236 (45.0) |
| Hypertension | 443 (84.4) |
| Hypercholesterolemia | 277 (52.8) |
| Depressed mood before stroke (n=511) | 160 (31.3) |
| Stroke etiologic subtypes, no. (%) | |
| Atherosclerotic | 79 (15.1) |
| Lacunar | 135 (25.7) |
| Cardioembolic | 86 (16.4) |
| Cryptogenic | 210 (40.0) |
| Stroke severity, No. (%) (n=431): | |
| NIHSS rating 0–5 | 234 (54.6) |
| NIHSS rating 6–13 | 152 (35.1) |
| NIHSS rating ≥14 | 45 (10.3) |
| Side of stroke, no. (%) right-sided (n=520) | 293 (56.4) |
| Incontinent of urine 7–10 days after stroke (n=481) | 139 (28.9) |

*Definitions of risk factors and stroke characteristics in text.
†All percentages calculated with n=525 unless otherwise noted.

To evaluate at which time point the greatest change occurs, we conducted an analysis of the change point in functional decline. The maximum likelihood estimate of the change point was at 3 years, and the change in proportion of participants with BI ≥95 before and after the 3-year time point was significantly different from zero (OR, 0.76; P=0.0088), indicating that the greatest functional decline began to occur 3 years after stroke.

There was no significant difference in functional status when those with shorter follow-up were compared with those with relatively longer follow-up, confirming that differential follow-up does not depend on functional status.

Other predictors of BI ≥95 among all participants were age at stroke, diabetes, marital status, stroke severity, and baseline urinary continence (Table 2). Results were similar for the BI cutoff of 60 with the exception that DM approached...
but did not reach significance as a predictor ($P=0.0842$) and marital status was not associated with outcome ($P=0.94$).

Left-sided stroke (versus right) was associated with better functional outcome. Among participants with BI $>95$ at 6 months, predictors were similar to those among all participants, except that Hispanic ethnicity was a significant predictor, whereas severe stroke was not (Table 3).

Table 2. Multivariate Generalized Estimating Equation Regression Model of Predictors of Function After Ischemic Stroke

<table>
<thead>
<tr>
<th>Variable</th>
<th>OR</th>
<th>95% CI of OR</th>
<th>$P$ Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time of follow-up assessment</td>
<td>0.91</td>
<td>0.84–0.99</td>
<td>0.019</td>
</tr>
<tr>
<td>Age at stroke</td>
<td>0.95</td>
<td>0.93–0.96</td>
<td>$&lt;0.0001$</td>
</tr>
<tr>
<td>Male sex</td>
<td>1.41</td>
<td>0.89–2.22</td>
<td>0.14</td>
</tr>
<tr>
<td>Race–ethnicity*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Black</td>
<td>0.88</td>
<td>0.42–1.86</td>
<td>0.74</td>
</tr>
<tr>
<td>Hispanic</td>
<td>1.05</td>
<td>0.50–2.17</td>
<td>0.91</td>
</tr>
<tr>
<td>At least high school education</td>
<td>1.64</td>
<td>0.94–2.87</td>
<td>0.082</td>
</tr>
<tr>
<td>Insured with Medicaid or uninsured</td>
<td>0.85</td>
<td>0.53–1.37</td>
<td>0.51</td>
</tr>
<tr>
<td>Physical activity</td>
<td>1.49</td>
<td>0.99–2.24</td>
<td>0.057</td>
</tr>
<tr>
<td>DM</td>
<td>0.48</td>
<td>0.32–0.73</td>
<td>0.0006</td>
</tr>
<tr>
<td>Married status</td>
<td>1.82</td>
<td>1.12–2.97</td>
<td>0.016</td>
</tr>
<tr>
<td>Coronary artery disease</td>
<td>0.72</td>
<td>0.47–1.09</td>
<td>0.12</td>
</tr>
<tr>
<td>Moderate stroke†</td>
<td>0.36</td>
<td>0.24–0.55</td>
<td>$&lt;0.0001$</td>
</tr>
<tr>
<td>Severe stroke†</td>
<td>0.06</td>
<td>0.02–0.18</td>
<td>$&lt;0.0001$</td>
</tr>
<tr>
<td>Urinary continence</td>
<td>3.80</td>
<td>2.27–6.36</td>
<td>$&lt;0.0001$</td>
</tr>
<tr>
<td>Left-sided stroke</td>
<td>1.48</td>
<td>0.99–2.22</td>
<td>0.059</td>
</tr>
</tbody>
</table>

*Compared with non-Hispanic white race–ethnicity.
†Compared with mild stroke.

Table 3. Multivariate Generalized Estimating Equation Regression Model of Predictors of Function After Ischemic Stroke Among Those With BI $>95$ at 6 Months

<table>
<thead>
<tr>
<th>Variable</th>
<th>OR</th>
<th>95% CI of OR</th>
<th>$P$ Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time of follow-up assessment</td>
<td>0.76</td>
<td>0.65–0.89</td>
<td>0.0005</td>
</tr>
<tr>
<td>Age at stroke</td>
<td>0.95</td>
<td>0.91–0.98</td>
<td>0.004</td>
</tr>
<tr>
<td>Male sex</td>
<td>1.25</td>
<td>0.65–2.41</td>
<td>0.50</td>
</tr>
<tr>
<td>Race–ethnicity*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Black</td>
<td>0.50</td>
<td>0.11–2.32</td>
<td>0.37</td>
</tr>
<tr>
<td>Hispanic</td>
<td>0.21</td>
<td>0.05–0.89</td>
<td>0.03</td>
</tr>
<tr>
<td>At least high school education</td>
<td>2.16</td>
<td>0.88–5.29</td>
<td>0.09</td>
</tr>
<tr>
<td>Insured with Medicaid or uninsured</td>
<td>0.97</td>
<td>0.48–1.98</td>
<td>0.94</td>
</tr>
<tr>
<td>Physical activity</td>
<td>1.33</td>
<td>0.69–2.56</td>
<td>0.39</td>
</tr>
<tr>
<td>DM</td>
<td>0.47</td>
<td>0.23–0.92</td>
<td>0.03</td>
</tr>
<tr>
<td>Married status</td>
<td>2.47</td>
<td>1.11–5.49</td>
<td>0.03</td>
</tr>
<tr>
<td>Coronary artery disease</td>
<td>0.58</td>
<td>0.29–1.16</td>
<td>0.12</td>
</tr>
<tr>
<td>Moderate stroke</td>
<td>0.33</td>
<td>0.16–0.67</td>
<td>0.002</td>
</tr>
<tr>
<td>Severe stroke</td>
<td>0.17</td>
<td>0.01–2.17</td>
<td>0.17</td>
</tr>
<tr>
<td>Urinary continence</td>
<td>5.42</td>
<td>2.18–13.50</td>
<td>0.0003</td>
</tr>
<tr>
<td>Left-sided stroke</td>
<td>1.08</td>
<td>0.58–2.04</td>
<td>0.80</td>
</tr>
</tbody>
</table>

*Compared with non-Hispanic white race–ethnicity.

Discussion

In this large, population-based, prospective cohort study of patients with first-time ischemic stroke, we observed a modest annual decline in functional status over the long term after stroke, even after censoring those with recurrent stroke and MI and adjusting for risk factors and baseline stroke severity. There was a significant decline over years of follow-up even among those with early functional “recovery” (BI $>95$ at 6 months). In the United States, there are 4 tiers of insurance access: private insurance (69% of the US population in 200426), Medicaid (a state-administered insurance only available to low-income residents that has been associated with limited access to health care in New York state27,28; 13% of the population), Medicare (a federally administered insurance primarily for residents aged $\geq 65$ years; 14% of the population), and no insurance.
(16% of population). Functional decline in our study was seen particularly among those who were uninsured or insured with Medicaid. This decline began to be apparent at approximately 3 years when we used as a threshold for disability the BI threshold of 95 and at 2 years with a BI cutoff of 60.

Few community-based studies have examined long-term disability after stroke. One study reported that 37% of patients with first stroke worsened in Rankin scores between 1 and 5 years after stroke in Rochester, Minn. Limitations of this study included comparison of mean Rankin scores without reporting of CIs and the lack of multivariable analysis for predictors of outcomes. Furthermore, the Generalized Estimating Equations analysis that was used in our study is more sensitive to individual changes in disability over time. In another study, in which dependence in activities of daily living tasks in 109 patients with first stroke was analyzed, a smaller percentage of women were independent at 5 years and there was a greater proportion of dependence among older patients. However, this study had a small sample, reported only percentages in each category without CIs or significance tests, did not conduct multivariable analysis, and used a potentially insensitive activities of daily living measurement scale. Another study examined modified BI at 5 years in 129 survivors of first stroke and found that 36% developed new major disability with predictors including older age, drowsiness at baseline assessment, moderate hemiparesis, and recurrent stroke. This study was limited by small numbers of data available at 5 years and only one follow-up assessment of disability. Finally, none of these studies censored recurrent stroke or cardiac events, and hence it is unclear whether worsened disability over time was the result of recurrent stroke or long-term effects of a single index stroke. In contrast to these studies, our study collected data at multiple time points and excluded those with recurrent clinical vascular events and so was able to assess a linear change in function over time.

The delayed functional decline that we observed has not been well described before and has several possible explanations. Nonstroke comorbidities that are known to affect functional status may contribute in the long-term as prior research in nonstroke cohorts has shown. In particular, cognitive dysfunction has been shown to be associated with functional status after stroke. In cognitive research, the concept of "cognitive reserve" refers to differing susceptibility to cognitive impairment that is related to variables such as education, literacy, intelligence quotient, and engagement in leisure activities. Considering the close correlation between cognitive status and functional status, there may be a similar phenomenon with regard to performing activities of daily living that we may term "functional reserve." The deficit caused by a first stroke may result in a depleted functional reserve and a consequent failure to compensate for brain aging. We were unable to include detailed measurements of cognitive function in our analyses, however.

Another possible explanation for the observed delay in functional decline among uninsured and Medicaid patients is that the stroke caused a functional deficit that affected participants equally regardless of insurance status. Stroke, in other words, may serve as a sort of equalizer of function due to its direct biological effects on the brain as well as the availability of acute rehabilitation and other therapies available to participants with all types of insurance. Over time after stroke, however, functional status among those with private insurance and Medicare and those with Medicaid or no insurance may diverge due to disparities in care and more limited access to rehabilitative services, information about health, and ongoing management of risk factors and chronic conditions that are known to have an impact on functional status.

The delayed decline in functional status could also be due to the ceiling effect that has been observed with the BI. It is possible that there was a steady decline in functional status that began soon after ischemic stroke, but because the BI is insensitive to small changes in disability, this decline was not captured until 3 years after the stroke.

Another possible explanation for the observed decline in functional status is that participants may have experienced clinically silent recurrent strokes during follow-up. Studies have shown a prevalence of 6% to 18% of clinically silent strokes in different populations depending on risk factors and imaging protocols, and silent infarcts may be as much as 5 times as prevalent as symptomatic infarcts. A previous study in the northern Manhattan population showed that 18% of 892 participants free of clinical stroke had subclinical infarcts. Despite the term "silent" stroke, these subclinical events may affect functional status.

Previous studies with limited follow-up have shown predictors of functional status similar to the predictors that we found, in particular age, DM, marital status (a marker of social support), stroke severity, side of stroke, and urinary continence. Most previous studies, however, have assessed these functional outcomes at single points in time, whereas in our analysis, we were able to assess the associations for these risk factors with functional outcomes measured at multiple annual intervals. These risk factors thus continue to predict functional status over several years. The fact that these predictors were found to be significant in our study suggests that they represent robust associations with functional status, because selection bias is minimized in population-based studies and follow-up continued to 5 years poststroke. The fact that DM was a significant predictor of...
functional outcome is notable considering the high preva-
lence of DM in this population, which is likely due to a
combination of environmental (including dietary) and genetic
factors.

In our multiethnic population-based study, race–ethnicity
was not associated with functional outcome among all par-
ticipants, in univariate or multivariate analyses. Socioeco-
nomic status and access to care were primary mediating
effects of functional status, perhaps mitigating the effect of
race–ethnicity on outcome, which has been previously
described.43

Limitations of this study include use of the BI to assess
disability instead of a disability scale designed specifically
for patients with stroke. However, the BI is widely used in
stroke research, which allows comparison of this study with
prior studies. Second, detailed data on rehabilitation received
after the stroke was not collected and may have informed the
relationship between late functional decline and insurance
status. Third, because some of the data on baseline risk
factors was obtained by self-report, uninsured participants
who do not regularly get medical care may not be aware of
undiagnosed conditions. Hence, to lessen bias, we used
laboratory and blood pressure measurements and information
about prescription medications to capture risk factors such as
DM, hypertension, and hypercholesterolemia. Fourth, neuro-
psychological data were not analyzed in this study, which
could have informed the link between cognitive status and
functional status. Future research will be directed toward
clarifying the relationship between time and functional de-
cline, comparing functional status over time in patients with
stroke and nonstroke control subjects matched for risk fac-
tors, and assessing the role of cognitive decline as a mediator
of the change in functional status. Finally, the decline in
functional status among those with less access to care
highlights the need to improve the ways in which knowledge
of risk factor control is translated in clinical practice to
improve outcome after stroke.

Sources of Funding
This work was supported by grants from the National Institute
of Neurological Disorders and Stroke (R01 NS48134, M.S.V.E.; R37
29993, R.L.S. and M.S.V.E.).

Disclosures
None.

References
1. Prevalence of disabilities and associated health conditions among
120–125.
3. Pan SL, Lien IN, Yen MF, Lee TK, Chen TH. Dynamic aspect of
functional recovery after stroke using a multistate model. Arch Phys Med
4. Hankey GJ, Spieser J, Hakimi Z, Bego G, Carita P, Gabriel S, Rate,
degree, and predictors of recovery from disability following ischemic
and survival following stroke: Psychological and clinical predictors of
6. Jorgensen HS, Reith J, Nakayama H, Kammergaard LP, Raaschou HO,
Olsen TS. What determines good recovery in patients with the most
severe strokes? The Copenhagen Stroke Study. Stroke. 1999;30:
7. Weimar C, Konig IR, Kraywinkel K, Ziegler A, Diener HC. Age and
National Institutes of Health Stroke Scale score within 6 hours after onset
are accurate predictors of outcome after cerebral ischemia: development
8. Weimar C, Ziegler A, Konig IR, Diener HC. Predicting functional
outcome and survival after acute ischemic stroke. J Neurol. 2002;249:
888–895.
with diabetes. The Copenhagen Stroke Study. Stroke. 1994;25:
10. Glass TA, Matchar DB, Belyea M, Feussner JR. Impact of social support
on outcome in first stroke. Stroke. 1993;24:64–70.
Lesion characteristics, NIH Stroke Scale, and functional recovery after
12. Robertson IH, Ridgeway V, Greenfield E, Parr A. Motor recovery after
stroke depends on intact sustained attention: a 2-year follow-up study.
13. Massucci M, Perdon L, Agosti M, Celani MG, Righetti E, Recupero E,
Todeschini E, Franceschini M. Prognostic factors of activity limitation
and discharge destination after stroke rehabilitation. Am J Phys Med
15. Putman K, De Witt L, Schoonacker M, Baert I, Beyens H, Brinkmann D,
Dondorp E, De Meyts P, De Weerd W, Fays H, Jennis W, Kuske C,
Leys M, Lincoln N, Schuback B, Schapp W, Smith B, Loucks F. Effect of
socioeconomic status on functional and motor recovery after stroke: a
European multicentre study. J Neurol Neurosurg Psychiatry. 2007;78:
593–599.
MC, Hauser WA. Stroke incidence among white, black, and Hispanic
residents of an urban community: the Northern Manhattan Stroke study.
17. Hartmann A, Rundek T, Mast H, Paik MC, Boden-Albala B, Mohr JP,
Sacco RL. Mortality and causes of death after first ischemic stroke: the
18. Sacco RL, Gan R, Boden-Albala B, Lin IF, Kargman DE, Hauser WA,
Shea S, Paik MC. Leisure-time physical activity and ischemic stroke risk:
19. Sacco RL, Elkind M, Boden-Albala B, Lin IF, Kargman DE, Hauser WA,
Shea S, Paik MC. The protective effect of moderate alcohol consumption
20. Gentry EM, Kalsbeek WD, Hogelin GC, Jones JT, Gaines KL, Forman
MR, Marks JS, Trowbridge FL. The behavioral risk factor surveys: II.
Design, methods, and estimates from combined state data. Am J Prev
Relationship of 6-month functional outcome and stroke severity: impli-
cations for acute stroke trials from the Northern Manhattan Stroke Study.
Rundek T, Snipes RG, Thompson JL. Glycine antagonist in neuropro-
tection for patients with acute stroke: GAIN America: a randomized
Testing the validity of the lacunar hypothesis: the Northern Manhattan
AR, Fishman IG, Roth AA, Barwick JA, Kunitz SC. Reliability of the
activities of daily living scale and its use in telephone interview. Arch
correlated data using generalized estimating equations: an orientation.
NJ. Insurance status predicts access to care and outcomes of vascular
28. Calman NS, Golub M, Ruddock C, Le L, Hauser D. Separate and unequal
Long-Term Functional Recovery After First Ischemic Stroke: The Northern Manhattan Study
Mandip S. Dhamoon, Yeseon Park Moon, Myunghee C. Paik, Bernadette Boden-Albala, Tatjana Rundek, Ralph L. Sacco and Mitchell S.V. Elkind

Stroke. 2009;40:2805-2811; originally published online June 25, 2009; doi: 10.1161/STROKEAHA.109.549576

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/40/8/2805

Permissions: Requests for permissions to reproduce figures, tables, or portions of articles originally published in Stroke can be obtained via RightsLink, a service of the Copyright Clearance Center, not the Editorial Office. Once the online version of the published article for which permission is being requested is located, click Request Permissions in the middle column of the Web page under Services. Further information about this process is available in the Permissions and Rights Question and Answer document.

Reprints: Information about reprints can be found online at:
http://www.lww.com/reprints

Subscriptions: Information about subscribing to Stroke is online at:
http://stroke.ahajournals.org/subscriptions/