Similar Motor Recovery of Upper and Lower Extremities After Stroke

Pamela W. Duncan, PhD, PT; Larry B. Goldstein, MD; Ronnie D. Horner, PhD; Pamela B. Landsman, MPH; Gregory P. Samsa, PhD; David B. Matchar, MD

Background and Purpose This study examined the validity of the clinical tenet that poststroke recovery of the upper extremity is less rapid and complete than poststroke recovery of the lower extremity. Previous studies comparing upper and lower extremity recovery have evaluated disability rather than motor impairment. Individuals with lower extremity impairments may be more functional and appear less disabled than individuals with upper extremity impairments. Function of the upper extremity requires finer motor control, for which the patient can less readily compensate. Therefore, impairments and disability would predictably be more highly correlated in this area. We tested the hypothesis that upper and lower extremity motor recovery are similar.

Methods The 95 patients selected for this study were enrolled in the Durham County Stroke Study and had been diagnosed with anterior circulation ischemic stroke. Each subject received Fugl-Meyer assessments within 24 hours of admission and then 5, 30, 90, and 180 days after stroke. We used these assessments to compare the time course and patterns of motor function of the upper and lower extremities.

Results Repeated-measures ANOVA revealed that percent maximal motor recovery was significantly (P<.001) affected by time after stroke but not by extremity (upper extremity versus lower extremity) (P=.32). When stroke severity level is controlled, the upper and lower extremities continue to show no difference in percent motor recovery (P=.19).

Conclusions In patients with anterior circulation ischemic stroke, the severity of motor impairment and the patterns of motor recovery are similar for the upper and lower extremities. The most rapid recovery for both extremities occurs within 30 days. (Stroke. 1994;25:1181-1188.)

Key Words • motor activity • rehabilitation • stroke outcome

Most individuals who survive stroke experience some degree of recovery. Recovery from the physiological impairments resulting from stroke (eg, motor deficits, abnormal sensation, aphasia, visuospatial neglect) can lead to recovery from stroke disabilities (eg, walking, dressing, bathing) and ultimately to a reduction of stroke handicaps (eg, return to work). Recovery at all levels probably reflects three different processes: resolution of acute pathological sequelae of stroke, intrinsic neuroplasticity, and behavioral compensation.1,2

The distinction between recovery at the impairment and disability levels is critical. Measurement of recovery at just one level gives only a partial picture of the entire recovery process. For example, many activities of daily living can be performed despite the presence of significant impairments. If only the level of disability is monitored the patterns of physiomeurological recovery may be disguised. Knowledge of both recovery patterns helps clinicians, patients, and patients’ families understand the prognosis for the maximum level of neurological and adaptive recovery. A distinct understanding of recovery from physiological stroke impairments is also critical for designing clinical trials that evaluate the effectiveness of specific treatment interventions.

Within the last few years, several investigators have begun to study the patterns of stroke recovery.3-9 The results of these studies show that most recovery occurs in the first 30 days but that improvement may continue as long as 6 to 12 months after stroke.6,10 The two best indicators of the potential for recovery from impairments are the initial severity of the neurological deficits and the early patterns of improvement. Patients who experience early and quick changes in motor function generally achieve a much higher level of maximum recovery.10,11

Initially, recovery from disability often parallels recovery from impairments. However, improvements in activities of daily living may continue after recovery at the impairment level has ceased.12 This continuation of improvement in activities of daily living despite stable deficits at the level of impairment is suggestive of further behavioral adaptation or compensation.

Recovery of arm movement is generally believed to be less than recovery of leg movement.13 However, this clinical tenet is often based on measures of disability rather than on tests of specific motor impairments of the upper and lower extremities. Individuals may have functional gait in the presence of major motor impairments in the lower extremity (ie, major impairment but limited disability). Because function of the upper extremity requires finer motor control, less disparity between impairment and disability would be expected.

The purpose of the present study was to compare the recovery of upper and lower extremities at the impair-
<table>
<thead>
<tr>
<th>Test</th>
<th>Scoring</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. Upper Extremity Reflexes</td>
<td>0: No reflex activity can be elicited</td>
</tr>
<tr>
<td>Biceps and/or finger flexors</td>
<td>2: Reflex activity can be elicited</td>
</tr>
<tr>
<td>Triceps</td>
<td></td>
</tr>
<tr>
<td>II. Movements</td>
<td></td>
</tr>
<tr>
<td>Shoulder elevation</td>
<td>0: Cannot be performed at all</td>
</tr>
<tr>
<td>Shoulder retraction</td>
<td>1: Performed partly</td>
</tr>
<tr>
<td>Abduction ($\geq 90^\circ$)</td>
<td>2: Performed faultlessly</td>
</tr>
<tr>
<td>External rotation</td>
<td></td>
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<tr>
<td>Elbow flexion</td>
<td></td>
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<tr>
<td>Forearm supination</td>
<td></td>
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<tr>
<td>Shoulder adduction/internal rotation</td>
<td></td>
</tr>
<tr>
<td>Elbow extension</td>
<td></td>
</tr>
<tr>
<td>Forearm pronation</td>
<td></td>
</tr>
<tr>
<td>a. Hand to lumbar spine</td>
<td></td>
</tr>
<tr>
<td>b. Shoulder flexion to 90$^\circ$</td>
<td></td>
</tr>
<tr>
<td>c. Pronation/supination of forearm with elbow at 90$^\circ$ and shoulder at 0$^\circ$</td>
<td></td>
</tr>
<tr>
<td>a. Shoulder abduction to 90$^\circ$, elbow at 0$^\circ$, and forearm pronated</td>
<td></td>
</tr>
<tr>
<td>b. Shoulder flexion 90$^\circ$-180$^\circ$, elbow at 0$^\circ$, and forearm in middle position</td>
<td></td>
</tr>
<tr>
<td>c. Pronation/supination of forearm elbow at 0$^\circ$ and shoulder flexion 30$^\circ$-90$^\circ$</td>
<td></td>
</tr>
<tr>
<td>III. Normal Reflex Activity</td>
<td>(This stage, which can render the score of 2, is included only if the patient has a score of 6 in the previous stage.)</td>
</tr>
<tr>
<td>Biceps and finger flexors and triceps</td>
<td></td>
</tr>
</tbody>
</table>

MP indicates metacarpophalangeal; PIPs, proximal interphalangeal joints; and DIPs, distal interphalangeal joints.
<table>
<thead>
<tr>
<th>Test</th>
<th>Scoring</th>
</tr>
</thead>
<tbody>
<tr>
<td>IV. Wrist Control</td>
<td></td>
</tr>
<tr>
<td>a. Stability, elbow at 90°, shoulder at 0°</td>
<td>a. 0: Patient cannot dorsiflex wrist to required 15°</td>
</tr>
<tr>
<td></td>
<td>1: Dorsiflexion is accomplished, but no resistance is taken</td>
</tr>
<tr>
<td></td>
<td>2: Position can be maintained with some (slight) resistance</td>
</tr>
<tr>
<td>b. Flexion/extension, elbow at 90°, shoulder at 0°</td>
<td>b. 0: Volitional movement does not occur</td>
</tr>
<tr>
<td></td>
<td>1: Patient cannot actively move the wrist joint throughout the total range of motion</td>
</tr>
<tr>
<td></td>
<td>2: Faultless, smooth movement</td>
</tr>
<tr>
<td>c. Stability, elbow at 0°, shoulder at 0°</td>
<td>c. Scoring is the same as for item a</td>
</tr>
<tr>
<td>d. Flexion/extension, elbow at 0°, shoulder at 0°</td>
<td>d. Scoring is the same as for item b</td>
</tr>
<tr>
<td>e. Circumduction</td>
<td>e. 0: Cannot be performed</td>
</tr>
<tr>
<td></td>
<td>1: Jerky motion or incomplete circumduction</td>
</tr>
<tr>
<td></td>
<td>2: Complete motion with smoothness</td>
</tr>
<tr>
<td>V. Hand Function</td>
<td></td>
</tr>
<tr>
<td>a. Finger mass flexion</td>
<td>a. 0: No flexion occurs</td>
</tr>
<tr>
<td></td>
<td>1: Some flexion but not full motion</td>
</tr>
<tr>
<td></td>
<td>2: Complete active flexion (compared with unaffected hand)</td>
</tr>
<tr>
<td>b. Finger mass extension</td>
<td>b. 0: No extension occurs</td>
</tr>
<tr>
<td></td>
<td>1: Patient can release an active mass flexion grasp</td>
</tr>
<tr>
<td></td>
<td>2: Full active extention</td>
</tr>
<tr>
<td>c. Grasp No. 1: MP joints extended, PIPs and DIPs flexed; grasp is tested against resistance</td>
<td>c. 0: Required position cannot be acquired</td>
</tr>
<tr>
<td></td>
<td>1: Grasp is weak</td>
</tr>
<tr>
<td></td>
<td>2: Grasp can be maintained against relatively great resistance</td>
</tr>
<tr>
<td>d. Grasp No. 2: Patient is instructed to adduct thumb, all other joints at 0°</td>
<td>d. 0: Function cannot be performed</td>
</tr>
<tr>
<td></td>
<td>1: Scrap of paper interposed between thumb and index finger can be kept in place but not against a slight tug</td>
</tr>
<tr>
<td></td>
<td>2: Paper is held firmly against a tug</td>
</tr>
<tr>
<td>e. Grasp No. 3: Patient opposes thumb pad of index finger; a pencil is interposed</td>
<td>e. Scoring procedures are the same as for grasp No. 2</td>
</tr>
<tr>
<td>f. Grasp No. 4: Patient grasps a cylinder-shaped object (small can), with the volar surfaces of the first and second fingers against each other</td>
<td>f. Scoring procedures are the same as for grasp Nos. 2 and 3</td>
</tr>
<tr>
<td>g. Grasp No. 5: A spherical grasp; patient grasps a tennis ball</td>
<td>g. Scoring procedures are the same as for grasp Nos. 2, 3, and 4</td>
</tr>
<tr>
<td>VI. Coordination/Speed: Finger to Nose (five repetitions)</td>
<td></td>
</tr>
<tr>
<td>a. Tremor</td>
<td>a. 0: Marked tremor</td>
</tr>
<tr>
<td></td>
<td>1: Slight tremor</td>
</tr>
<tr>
<td></td>
<td>2: No tremor</td>
</tr>
<tr>
<td>b. Dysmetria</td>
<td>b. 0: Pronounced or unsystematic dysmetria</td>
</tr>
<tr>
<td></td>
<td>1: Slight or systematic dysmetria</td>
</tr>
<tr>
<td></td>
<td>2: No dysmetria</td>
</tr>
<tr>
<td>c. Speed</td>
<td>c. 0: Activity is &gt;6 seconds longer than unaffected hand</td>
</tr>
<tr>
<td></td>
<td>1: 2-5 seconds longer than unaffected hand</td>
</tr>
<tr>
<td></td>
<td>2: &lt;2 seconds' difference</td>
</tr>
<tr>
<td>Test</td>
<td>Scoring</td>
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<tr>
<td>----------------------------------------------------------------------</td>
<td>--------------------------------------------------</td>
</tr>
<tr>
<td><strong>Lower Extremities</strong></td>
<td></td>
</tr>
<tr>
<td>I. Reflex Activity: Tested in Supine Position</td>
<td>0: No reflex activity</td>
</tr>
<tr>
<td>Achilles</td>
<td>2: Reflex activity</td>
</tr>
<tr>
<td>Patellar</td>
<td></td>
</tr>
<tr>
<td>II. Movements</td>
<td></td>
</tr>
<tr>
<td>a. Supine position</td>
<td>a. 0: Cannot be performed</td>
</tr>
<tr>
<td>Hip flexion</td>
<td>1: Partial motion</td>
</tr>
<tr>
<td>Knee flexion</td>
<td>2: Full motion</td>
</tr>
<tr>
<td>Ankle dorsiflexion</td>
<td></td>
</tr>
<tr>
<td>b. Supine: motion is resisted</td>
<td>b. 0: No motion</td>
</tr>
<tr>
<td>Hip extension</td>
<td>1: Weak motion</td>
</tr>
<tr>
<td>Adduction</td>
<td>2: Almost full strength compared with normal</td>
</tr>
<tr>
<td>Knee extension</td>
<td></td>
</tr>
<tr>
<td>Ankle plantar flexion</td>
<td></td>
</tr>
<tr>
<td>a. Knee flexion beyond 90°</td>
<td>a. 0: No active motion</td>
</tr>
<tr>
<td></td>
<td>1: From slightly extended position knee can be flexed but not beyond 90°</td>
</tr>
<tr>
<td></td>
<td>2: Knee flexion beyond 90°</td>
</tr>
<tr>
<td>b. Ankle dorsiflexion</td>
<td>b. 0: No active flexion</td>
</tr>
<tr>
<td></td>
<td>1: Incomplete active flexion</td>
</tr>
<tr>
<td></td>
<td>2: Normal dorsiflexion</td>
</tr>
<tr>
<td>Hip at 0°</td>
<td></td>
</tr>
<tr>
<td>a. Knee flexion</td>
<td>a. 0: Knee cannot flex without hip flexion</td>
</tr>
<tr>
<td></td>
<td>1: Knee begins flexion without hip flexion but does not get to 90°, or hip flexes during motion</td>
</tr>
<tr>
<td></td>
<td>2: Full motion as described</td>
</tr>
<tr>
<td>b. Ankle dorsiflexion</td>
<td>b. 0: No active motion</td>
</tr>
<tr>
<td></td>
<td>1: Partial motion</td>
</tr>
<tr>
<td></td>
<td>2: Full motion</td>
</tr>
<tr>
<td>III. Normal Reflexes</td>
<td>0: Two of the 3 are markedly hyperactive</td>
</tr>
<tr>
<td>Knee flexors</td>
<td>1: One reflex is hyperactive, or 2 reflexes are lively</td>
</tr>
<tr>
<td>Patellar</td>
<td>2: No more than 1 reflex is lively</td>
</tr>
<tr>
<td>Achilles</td>
<td></td>
</tr>
<tr>
<td>IV. Coordination/Speed: Heel to Opposite Knee (five repetitions)</td>
<td></td>
</tr>
<tr>
<td>a. Tremor</td>
<td>a. 0: Marked tremor</td>
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<td>c. Speed</td>
<td>c. 0: &gt;5 seconds slower than unaffected side</td>
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ment level rather than the disability level. The major hypotheses were that (1) both the upper and lower extremities recover some degree of motor control after stroke, (2) the recovery from motor impairments is similar for both upper and lower extremities, and (3) any difference between upper and lower extremity impairments depends on the severity of the impairments immediately after the stroke.

**Subjects and Methods**

**Design**

Data for this study were collected as part of an observational cohort study originally designed to investigate the significance of serum glucose levels in regard to stroke recovery.4 The cohort patients were individuals admitted with a new anterior circulation ischemic stroke between January 1987 and October 1989 at Duke University Medical Center, Durham County Hospital, or the Durham Department of Veterans Affairs Medical Center. The original study protocol was approved by the Institutional Review Board of each participating hospital.

**Inclusion/Exclusion Criteria**

Patients included in the study had to (1) be able to give informed consent personally or by proxy, (2) be at least 40 years of age, (3) live within 100 miles of Duke University Medical Center, (4) be hospitalized within 24 hours of onset of neurological symptoms, (5) have a measurable neurological deficit present on admission, (6) have no preexisting stroke deficit, (7) have a persistent neurological deficit for more than 24 hours, and (8) have no other medical condition from which death is likely to occur within 6 months. Patients were excluded if they had (1) hemorrhagic stroke; (2) vertebrobasilar distribution stroke; (3) risk factors for embolic stroke, including cardiomyopathy, anteroseptal myocardial infarction in the previous 6 months, new atrial fibrillation, or a prosthetic heart valve; and (4) major medical comorbidities (eg, amputations, severe chronic obstructive pulmonary disease, severe arthritis) that would make assessment of motor function difficult. For this study subjects were excluded from analysis if they did not have Fugl-Meyer assessments at 5, 30, 90, and 180 days after stroke.

**Measurement**

The Fugl-Meyer assessment was used to measure recovery of motor control. It is a 226-point scoring system that includes range of motion, pain, sensation, motor function of the upper and lower extremities, and balance.15,16 This instrument provides a reliable and valid measure of specific motor function that is also sensitive to change. For the purposes of this study, assessment of recovery was limited to the motor function component (100 points) of the assessment (Table 1).

The assessments of motor impairment were made by a study nurse or physician's assistant trained to use the Fugl-Meyer. Training included a review of a videotape plus up to five sessions with a physical therapist experienced in using the assessment. Measurements of motor function were made within 24 hours of admission and at 5, 30, 90, and 180 days after stroke. The evaluators obtained motor scores in the hospital and, after discharge, at the patient's home.

**Data Analysis**

To obtain the dependent variable(s), we first calculated Fugl-Meyer scores for the upper and lower extremities at baseline and at days 5, 30, 90, and 180. To place the upper and lower extremity data in the same scale, we then divided the above scores by the total possible score for that extremity (66 for upper, 34 for lower), obtaining a percentage of maximum possible recovery ("percent recovery").

**Results**

One hundred forty-six patients were originally enrolled in the Durham County Stroke Study. Comparison of recovery patterns was limited to 95 patients (79% of those who survived 180 days). Patients were excluded if they had died before the 6-month assessment or if the Fugl-Meyer measures were missing at any of the five time points.

Table 2 provides the demographic and clinical characteristics of the 95 patients assessed. Sixty percent of the sample were male, and 71.5% were white. The mean age of the sample was 67.7±10.5 years. Many of the enrolled patients had significant comorbidities, including diabetes, hypertension, and heart disease. Twenty-two percent of the patients had experienced a prior transient ischemic attack, and 18% had a previous minor stroke from which they had recovered fully before the current admission.

Graphic representation of the mean percentage of maximal motor scores for both the upper and lower extremities after stroke reveals that, in general, the
Fig 1. Line graph shows mean percentage of motor function recovered for upper (©) and lower (•) extremities in all patients.

The degree of recovery and the time course of recovery for the upper and lower extremities are very similar (Fig 1).

Fig 2 provides a profile of recovery of the upper and lower extremities for the four levels of initial severity. Both extremities improve motor function over time ($P = .0001$), and the most improvement occurs in the first 30 days. The patterns of recovery are similar for the upper and lower extremities ($P = .32$). Because of a ceiling effect in patients with mild stroke, there is a minimal ability to detect improvement over time.

Fig 3 shows the percentage of recovery at 180 days for the upper and lower extremities for each individual, stratified by level of initial stroke severity. These plots of motor functions for individual patients demonstrate that in some individuals there may be disparity in upper and lower extremity function, but for most individuals the motor functions of upper and lower extremities are similar. These figures also demonstrate that in patients with initially severe motor deficits there is great heterogeneity in outcomes. Some patients who were initially severely impaired experienced dramatic recovery, whereas others changed little.

**Discussion**

The results of this study do not support the clinical tenet that recovery after stroke is less rapid and complete in the upper extremity than in the lower extremity. This study of recovery of upper and lower extremity function used specific measures of motor impairment that were distinct from measures related to activities of daily living (disability measures), which reflect compensation as well as intrinsic physiological recovery. In both clinical practice and clinical research, it is important to distinguish intrinsic recovery from compensation. Understanding the actual level of recovery will assist clinicians in developing appropriate levels of therapeutic intervention. For example, clinicians will have a better basis for selecting interventions that enhance motor function or teach patients to compensate for their neurological deficits. Clini-
Fig 3. Scatterplots show percentage of motor function recovered at 180 days for each patient by severity of impairment at baseline, severe impairment (top left), moderate-severe impairment (top right), mild-moderate impairment (bottom left), and mild impairment (bottom right). The ordinate is the percentage of motor function recovered for the lower extremities; the abscissa is the percentage of motor function recovered for the upper extremities.

ical researchers will be able to distinguish physiological recovery from compensatory strategies to assess the effectiveness of various interventions.

There are several limitations to this study. First, the subjects in this study were restricted to individuals with anterior circulation nonembolic ischemic strokes. It may not be possible to generalize the results to other arterial distributions (posterior circulation) or to individuals with recurrent stroke or other stroke types (hemorrhagic or thromboembolic).

Second, the sample size for this study was small, and when patients were stratified by severity, some strata had small numbers (ie, the moderate-severe strata had only 12 patients). Subsequently, we did not have sufficient sample size to detect small differences in recovery patterns among the severity strata.

Third, because of limited sample size, the study did not examine other important covariates, such as age, comorbidities, preexisting function, and cognition. Future studies with larger sample sizes should also stratify on these important covariates and assess interactive effects. Finally, the original cohort study did not include performance-based measures of upper or lower extremity function (ie, timed functional movements of the upper extremity, nine-hole peg test, Jebsen hand function, or velocity of gait). Our assessment of changes is based on statistically significant measures of motor impairment rather than assessment of "clinically meaningful change" as may be captured by functional performance measures. Future studies should relate changes in motor control with changes in functional use of the upper and lower extremities.

In conclusion, the severity of motor impairments and the patterns of motor recovery from impairments are similar for the upper and lower extremities. Recovery of motor function in both the upper and lower extremities is most rapid in the first 30 days. Understanding these patterns of recovery will help clinicians make realistic prognoses for return of motor control as well as assist us in designing therapeutic strategies and planning clinical research studies to evaluate the effectiveness of therapeutic interventions.

Acknowledgment

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References

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