Rehabilitation Outcome Following Initial Unilateral Hemispheric Stroke
Life Table Analysis Approach
Michael J. Reding, MD, and Ernesto Potes, MD

Life table analysis is a powerful statistical tool that has become the preferred technique for studying both the natural history of and the effect of treatment on disease outcome. We have found only one report using life table analysis to study rehabilitation outcome after stroke. We assessed the recovery of both independent ambulation and overall self-care function in 95 consecutive patients with unilateral hemispheric stroke using life table analysis. Our results support the segregation of patients into the following prognostic subgroups at the time of entry into the rehabilitation program (mean ± SD 5 ± 3 weeks after stroke): 1) motor deficit only, 2) motor deficit plus somatic sensory deficit, and 3) motor deficit plus somatic sensory deficit plus homonymous visual deficit. The probabilities of reaching independence in ambulation, being able to walk 150 feet with assistance, reaching independence in self-care function, and reaching a point of assisted self care (Barthel Index score of ≥ 60) are highly significantly different among subgroups. The interval after stroke required to reach the plateau phase of recovery is also significantly different among subgroups. We propose that life table analysis can be used 1) to define patient outcome goals, 2) to define the time required to reach such goals, 3) to identify patients with medical or behavioral comorbidity who are functioning below their expected level, and 4) to assess the effect of alternative treatment regimens on both final outcome and time to reach that outcome. (Stroke 1988;19:1354-1358)

Jongbloed recently reviewed 33 studies of rehabilitation outcome predictors. She found a general consensus that history of stroke, older age, urinary and bowel incontinence, and visuospatial deficits were adverse prognostic indicators of final walking ability and self-care function. She discussed predicting change in functional scores versus predicting the patients' final level of function. Comparisons among studies were hindered by different patient samples, different criteria by which outcome was measured, different timing of outcome assessments, and the lack of validation of the measurement instruments used.

In an effort to systematically predict outcome, we focused on patients with initial unilateral hemispheric stroke; this represents the largest group of patients considered for rehabilitation referral. From past experience it was apparent that all strokes are not the same and that some indicator of the extent of neurologic injury is required to allow comparison of our study group with those of other institutions. We tried to categorize patients with stroke according to the arterial distribution affected, but from the literature we found a poor correlation between the artery proven by angiography to be occluded and both the computed tomography (CT scan) and cerebral blood flow estimate of infarct size and location. An alternative method of categorizing stroke is according to lesion location. Attempts at this using the atlas of Matsui and Hirano for the definition of lesion location on CT scan or magnetic resonance imaging (MRI) were handicapped by the fact that lesions usually involved multiple lobes and had variable degrees of cortical versus subcortical extension. We were not able to define how much of a lobe had to be involved by the lesion to score it as "affected." Attempts at quantifying lesion size by CT or MRI criteria are handicapped by the fact that patients are referred from different institutions with different imaging systems. Such a classification scheme is further confounded by the fact that lesion location is often more relevant to patient function than lesion size.

The above problems are eliminated by categorizing patients on the basis of their motor, somatic sensory, and visual field deficits, which has proven...
useful in studying the prevalence and clinical course of a number of poststroke complications such as incontinence, shoulder-hand syndrome, venous thromboembolism, and depression.\textsuperscript{6–8} Using standardized techniques for assessing strength, sensation, and visual fields, good interrater reliability can be achieved\textsuperscript{9,10} and can be increased further by forcing choices as to whether these neurologic parameters meet criteria for being scored as normal or abnormal. Rehabilitation outcome according to neurologic deficit category at different institutions can thereby be compared.

Jongbloed\textsuperscript{1} indicated that the variable timing of outcome assessments has made outcome comparisons difficult. Life table analysis allows the outcome data to be presented as a continuum that defines outcome status at any point in time along the curve,\textsuperscript{11} which facilitates comparison of the results with studies presenting data at only fixed time intervals.

The final confounding variable that has handicapped comparisons of stroke rehabilitation outcome assessment is the use of nonstandardized outcome scales. There are now several widely accepted outcome scales that assess both walking ability and self-care function.\textsuperscript{12,13} The Barthel Index\textsuperscript{13} has been the most widely used scale to report stroke outcome data and was adopted by The Burke Rehabilitation Center in 1980. Standardization of this outcome measure in our unit has been published.\textsuperscript{8}

In an effort to address the problems raised by the review article of Jongbloed\textsuperscript{1} we initiated the following study of stroke rehabilitation outcome.

**Subjects and Methods**

Ninety-five consecutive patients with initial unilateral hemispheric stroke who were admitted to an inpatient stroke rehabilitation unit directly from the acute-care hospital and who were examined by the participating neurologist comprise the study group. The diagnosis of stroke was based on the clinical history, neurologic examination, and CT or MRI head scan in each patient. The neurologic examination was scored before review of CT or MRI results. Patients were screened prior to acceptance into the rehabilitation unit and were rejected if they had any of the following exclusion criteria: 1) walking without assistance (referred to the outpatient program), 2) Class 3 or 4 congestive heart failure or ischemic heart disease as defined by the American Heart Association, 3) overriding orthopedic or rheumatologic problems that precluded walking before the stroke, and 4) resistive-assaultive behavior not responsive to pharmacologic intervention. Patients were accepted irrespective of age, prestroke living arrangements, severity of aphasia, apraxia, or socioeconomic level. Costs were covered by Medicare, Medicaid, or private insurance. The study group thus contained patients with a broad range of neurologic and neuropsychiatric abnormalities thought to represent the patient mix seen in most inpatient rehabilitation units.

Motor strength was assessed using the Medical Research Council 0-to-5-point scale.\textsuperscript{14} If lower extremity proximal (iliopsoas) muscle strength was \( \leq 4 \) the patient had a motor deficit. Proximal muscle strength was scored because distal leg weakness, even if profound, can be overcome by the use of a cane and bracing. Upper limb strength was not scored because patients can reach independence in self-care function and ambulation using one-handed techniques.

Somatic sensation was assessed using a variation of the hand localization task.\textsuperscript{15} The index finger of the affected hand was displaced into the extremes of all four spatial quadrants. The patient's error in locating the index finger of his or her affected hand in the spatial quadrant with the poorest performance with his or her unaffected hand with the eyes occluded was scored in inches. A mean error in the most affected quadrant of \( \geq 6 \) inches indicated somatic sensory deficit. Patients who were unable to comprehend this finger displacement task even after repeated gestural cues were scored as abnormal. Previous studies have shown that more subjective assessments of primary sensation (touch, temperature, pin, position, and vibration sense) have poor interrater reliability even in patients with intact language.\textsuperscript{9} Evaluation of a patient population half of which can be expected to have varying degrees of aphasia led us to adopt the finger displacement task as a measure of sensory deficit.

The presence or absence of homonymous hemianopsia was tested by confrontation visual field testing. Globally aphasic patients were tested by visual threat response. Interrater reliability has been previously reported.\textsuperscript{9} Visual neglect to double simultaneous stimulation was assessed but was less relevant for outcome than the presence of hemianopsia (unpublished results).

Based on the above criteria, most patients could be categorized as having one of the following three spectra of neurologic deficits: 1) motor deficit only (M deficit), 2) motor deficit plus somatic sensory deficit (MS deficit), or 3) motor deficit plus somatic sensory deficit plus homonymous visual deficit (MSV deficit). Patients with other combinations of deficits, that is, somatic sensory deficit plus homonymous visual deficit, motor deficit plus homonymous visual deficit, pure somatic sensory deficit, and pure homonymous visual deficit are infrequently seen in inpatient rehabilitation populations.

Using the Barthel Index,\textsuperscript{13} outcome was measured prospectively at 2-week intervals by the therapy team, which was unaware of this study or its purpose. The Barthel Index defines independent ambulation and ability to walk 150 feet with assistance. The use of a cane and ankle brace do not constitute assistance. Patients require assistance when the presence of another individual for patient safety (i.e., contact guarding, minimal assistance, etc.) is needed.
**TABLE 1. Demographic Data for 95 Patients With Unilateral Hemispheric Stroke**

<table>
<thead>
<tr>
<th>Subgroups</th>
<th>Motor deficit only (n=27)</th>
<th>Motor + sensory deficits (n=32)</th>
<th>Motor + sensory + visual deficits (n=32)</th>
<th>Other combinations of deficits (n=4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Study group (N=95)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age (yr)</td>
<td>66±12</td>
<td>64±16</td>
<td>67±9</td>
<td>66±10</td>
</tr>
<tr>
<td>Sex (male/female)</td>
<td>54/41</td>
<td>15/12</td>
<td>19/13</td>
<td>18/14</td>
</tr>
<tr>
<td>Interval from stroke onset to rehabilitation admission (days)</td>
<td>32±23</td>
<td>27±15</td>
<td>32±22</td>
<td>37±30</td>
</tr>
<tr>
<td>Initial Barthel Index score</td>
<td>48±22</td>
<td>67±16</td>
<td>49±15</td>
<td>31±18</td>
</tr>
<tr>
<td>Duration of rehabilitation hospital stay (days)</td>
<td>58±25</td>
<td>40±12</td>
<td>57±23</td>
<td>71±27</td>
</tr>
<tr>
<td>Final Barthel Index score</td>
<td>66±22</td>
<td>81±14</td>
<td>67±18</td>
<td>52±22</td>
</tr>
</tbody>
</table>

Data are mean ± SD, except for sex.

*Significance assessed using χ² statistic for 2 x 3 table, collapsing fourth and fifth columns.

One-way analysis of variance was used to compare interval data, and the χ² statistic was used to compare sex ratios. Actuarial life table analysis was performed as described by Rimm et al.11 Life table curves for the subgroups were compared using the Mantel-Haenszel log-rank method.11

**Results**

Table 1 lists the demographic data for our study group. The age, sex ratio, and interval after stroke did not differ significantly among the subgroups. The initial Barthel Index score, the duration of rehabilitation hospitalization, and the final Barthel Index scores were all significantly different among the subgroups. Further analysis of the subgroup with “other combinations of deficits” was not possible due to the small number of patients it contained.

Figure 1 presents the life table curve for independence in walking ≥150 feet for the three remaining subgroups. This outcome goal is a reasonable one for M deficit patients as >90% reached this goal by 14 weeks after their stroke. Only 35% of MS deficit patients and 3% of MSV deficit patients reached this outcome goal even though they were followed longer after their stroke (p<0.001).

Figure 2 presents the life table curves for ability to walk 150 feet with assistance for the three subgroups. This is a reasonable outcome as >90% of the patients in each subgroup attained it. The mean time after stroke at which each subgroup reached this goal is significantly different: M deficit subgroup, 14 weeks; MS deficit subgroup, 22 weeks; and MSV deficit subgroup, 28 weeks (p<0.001).

Figure 3 presents the life table curves for reaching independence in ambulation and self-care function, defined as a Barthel Index score of ≥95. The M deficit and MS deficit subgroups had a similar overall probability of reaching this goal but did so over highly significantly different times (p<0.001). The MSV deficit subgroup had very little likelihood of ever reaching this goal.

Figure 4 presents the life table curves for reaching the goal of walking with assistance and assisted self-care function, defined as a Barthel Index score of ≥60. Previous authors have indicated that this is the point at which a patient becomes easy to manage in the home. The patient no longer requires effortful assistance but only occasional help in rising from sitting to standing, a little lateral support for balance loss, etc. This level of assistance can usually be provided by an aged spouse trained in hemiplegic dressing, transfer, and walking techniques. This is a reasonable outcome goal for even the most impaired MSV deficit subgroup. Approx-
approximately 50% of such patients reached this goal compared with 70% of those with MS deficit and 97% of those with M deficit ($p<0.001$).

**Discussion**

From Table 1 and the figures it is apparent that patients with M, MS, and MSV deficits have very different outcome probabilities for the outcome measures assessed. The time after stroke required to achieve the outcome goals is also significantly different among subgroups.

Life table analysis provides data for setting patient rehabilitation goals. Based on the data in Figure 1, patients entering the rehabilitation unit with only M deficit can be expected to be independent in ambulation by 14 weeks after the stroke; patients with MSV deficit have little likelihood of becoming independent ambulators irrespective of time after stroke. Figure 2 shows that patients with MSV deficit, although they will not be independent ambulators, will reach a point of walking with assistance for distances of $\geq 150$ feet, which allows these patients to move about within the home. They may take up to 28 weeks after the stroke to reach this goal.

Similar comments can be made for setting self-care goals for each patient subgroup. Life table curves provide a statistical basis for setting expected times for reaching the Barthel Index score goals presented in Figures 3 and 4.

Life table analysis curves can indicate otherwise unrecognized comorbid medical-behavioral problems. Figure 2 shows that a patient with only M deficit who is not walking 150 feet with assistance by 8 weeks after the stroke is in the lowest 20% of his or her outcome subgroup. If the patient is not walking 150 feet with assistance by 12 weeks, he or she is in the lowest 7% of his or her outcome subgroup. One would question the presence of confounding medical, neurologic, or behavioral problems impeding the patient’s progress.

Once patients have been categorized into meaningful outcome probability subgroups, one can begin to compare the effect of rehabilitation techniques on life table outcome curves. Such analysis allows the investigator to determine both the effect of treatment on overall functional outcome and on the time required to reach the desired outcome goal.

Our life table outcome curves were generated while the patients participated in an inpatient rehabilitation program. Patients were censored when they left the program if they had not yet reached their respective outcome goal. Continuation of patient assessment after shifting to outpatient or in-home rehabilitation is difficult to interpret. Sub-

![Figure 2. Life table analysis of probability of walking $\geq 150$ ft with assistance. O, patients with motor deficit only (n=27); □, patients with motor deficit plus somatic sensory deficit (n=32); △, patients with motor deficit plus somatic sensory deficit plus homonymous visual deficit (n=32).](image)

![Figure 3. Life table analysis of probability of reaching Barthel Index score of $\geq 95$. O, patients with motor deficit only (n=27); □, patients with motor deficit plus somatic sensory deficit (n=32); △, patients with motor deficit plus somatic sensory deficit plus homonymous visual deficit (n=32).](image)
sequent lack of improvement might be due to less intensive therapy or to an intrinsic slowing of patient recovery.

The life table curves in Figures 2 and 3 demonstrate that in our study group with unilateral hemispheric stroke, persistent inpatient rehabilitation efforts result in functional gains in walking with assistance and independent self-care for up to 22–28 weeks after the stroke. We cannot comment on outcome results for outpatient or in-home rehabilitation. One would expect life table curves for patients given variable periods of inpatient rehabilitation and subsequent outpatient or in-home rehabilitation to show different outcome probabilities and time courses than those we present here. We interpret our data to represent the expected outcome for rather severely affected stroke victims given optimal inpatient rehabilitation care.

There is a pressing need for more objective criteria for determining rehabilitation outcome goals and the time required to reach these goals. Categorization of patients into readily verifiable subgroups and the use of life table analysis data may meet this need.

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References


KEY WORDS • cerebrovascular disorders • rehabilitation

FIGURE 4. Life table analysis of probability of reaching Barthel Index score of ≥60. O, patients with motor deficit only (n = 27); □, patients with motor deficit plus somatic sensory deficit (n = 32); △, patients with motor deficit plus somatic sensory deficit plus homonymous visual deficit (n = 32).
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