Prediction of Function After Stroke: 
A Critical Review

LYN JONGBLOED, PH.D.

SUMMARY A review of 33 studies identifies the factors of prior stroke, older age, urinary and bowel incontinence, and visuo-spatial deficits as adverse prognostic indicators of function. No relationship is shown between sex, hemisphere of stroke, and functional outcome. Functional admission score is a strong predictor of discharge functional status, but its relationship with improvement in function is unclear. Findings regarding the prognostic value of severity of paralysis and onset-admission delay are ambiguous. Comparison among studies is hindered by differences in patient samples, timing of assessments, criteria by which outcome is measured and measuring instrument used. Future studies should measure function at set times post-stroke, use functional scales whose reliability and validity is well established, and be conducted in several treatment centers to ensure that the sample is representative of the population to which the predictor measure is to be applied.

STROKE as a leading cause of disability necessitates the expenditure of considerable resources for the rehabilitation of its victims. As a result, identifying factors that predict functional recovery after stroke has been the subject of much research. It has been argued that certain subgroups of the stroke population may benefit more than others from specific rehabilitation services and that, in order to achieve the most efficient use of such services, it is important to identify predictors that discriminate between stroke patients with good and poor prognoses.

Prognostic indicators derived from clinical features or patient characteristics have been used to predict survival, discharge disposition, length of hospital stay, functional, and neurological status. This paper presents a selective, critical review of reports that predict functional recovery from assessment of patient characteristics within 3 months after the stroke. Patient characteristics most frequently associated with functional recovery are discussed, the literature is critiqued, and recommendations are made for future studies on prognostic indicators for stroke patients.

Prognostic Significance of Patient Characteristics

Table 1 summarizes the principal dimensions of 33 studies conducted between 1950 and 1986 which are reviewed in this paper. Only those studies are included in which a systematic attempt was made to measure function several weeks or months after admission and to relate this to patient characteristics measured earlier in the hospital stay. There were considerable differences in the primary goals of these studies; some sought to examine the prognostic value of a single variable, others to identify the most important predictors of functional outcome, while several described functional recovery of stroke patients. For the purpose of this paper, function is defined as the ability to perform activities of daily living. In some studies this refers to eating, dressing and grooming; in others, it includes transfers and ambulation.

Age

The prognostic significance of age is not altogether clear, although data tend to favor the interpretation that older patients have less favourable functional outcomes than younger ones. Fourteen studies found age to be negatively correlated with function on or after discharge, whereas 4 studies report no correlation between these variables. Lehmann found age to be negatively correlated with discharge function but to have no association with improvement in function, stating that this could be explained by the fact that some of the younger people in the study were less impaired, and consequently, had less room for improvement. Discharge function and improvement in function are very different measures, and this may explain the differences cited above. Three of 4 studies which found no relationship between age and function used improvement in function as the outcome measure; whereas in 12 of the 14 studies which found a negative relationship between age and function, the outcome measure was discharge function.

It is not possible to determine from these studies whether age is significant in itself or indirectly through associated diseases. The increased incidence of chronic disease (such as coronary heart disease, congestive heart failure, diabetes and hypertension) in older people is a possible explanation for the negative correlation between age and function on discharge.

Sex

No differences in functional recovery related to sex were found by the 7 studies which included sex as a potential predictor variable.

Previous Stroke

A previous stroke is an adverse prognostic indicator of function. All 4 studies which included this as a variable found a negative relationship between a previous stroke and functional outcome.

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<th>Outcome Measure</th>
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<tr>
<td>Rosenthal²⁹</td>
<td>to examine correlation between performance on perceptual tests and improvement in functional status</td>
<td>49 right CVA patients; age range 25–83 years</td>
<td>48 hours after admission to rehab. center; time post-stroke not noted</td>
<td>Hooper Visual Organization Test, Benton Visual Retention Test, Benton Copy Scores</td>
<td>positive (with discharge score)</td>
<td>none</td>
<td>improvement in functional status, and functional status on discharge</td>
</tr>
<tr>
<td>Rankin¹</td>
<td>to determine prognostic value of age, previous stroke, bilateral signs</td>
<td>192 patients over 40 years of age. Diagnoses: thrombosis 88%, embolism 9%, SAH 3%</td>
<td>3 weeks post-stroke</td>
<td>age, previous stroke, presence of bilateral signs</td>
<td>negative, negative, negative</td>
<td>yes</td>
<td>functional status on discharge</td>
</tr>
<tr>
<td>Bruell²</td>
<td>to identify factors predictive of improvement in function</td>
<td>80 patients, mean age 65 years</td>
<td>after admission to rehab. center; average 40 days post-stroke</td>
<td>age, systolic blood pressure, onset-admission interval</td>
<td>negative, negative, negative</td>
<td>yes</td>
<td>functional status on discharge</td>
</tr>
<tr>
<td>Bourestom¹⁵</td>
<td>to identify factors predictive of improvement in function</td>
<td>53 patients, mean age 64 years. Diagnoses: thrombosis 79%, embolism 7%, hemorrhage 3.7%, brain stem lesion 3.7%, unknown 6%</td>
<td>7 days after admission to rehab. center; time post-stroke not noted</td>
<td>previous cerebrovascular disease, bowel incontinence, urinary incontinence, systolic blood pressure, functional status on admission, onset-admission interval, sitting balance on admission, locomotion on admission, hemisphere of stroke, age, sex, socioeconomic status</td>
<td>negative, negative, negative, negative, negative, negative</td>
<td>yes (Kenny self-care evaluation)</td>
<td>improvement in functional status</td>
</tr>
<tr>
<td>Bourestom³⁰</td>
<td>to examine the value of a battery of psychological tests in predicting improvement in self-care</td>
<td>160 patients, mean age 64 years</td>
<td>average time, 3 months post-stroke</td>
<td>Wechsler Performance IQ, Wechsler Memory Scale, Graham-Kendall memory for Design, Knox Cubes, Seguin Form Board, Porteus Maze Test</td>
<td>positive for patients with low functional status on admission, positive for patients with moderate functional status on admission</td>
<td>none, none, none, none</td>
<td>improvement in functional status</td>
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</tbody>
</table>

Table 1: Summary of Studies on Prognostic Indicators in CVA Patients which Use Functional Status as the Outcome Measure
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<tr>
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<tr>
<td>Andersen</td>
<td>to examine the effectiveness of a rehabilitation program</td>
<td>82 patients, mean age 54 years. Diagnoses: arteriosclerosis 78%, aneurysm 10%, embolism 6%, brain tumour 4%, trauma 2%, other 2%</td>
<td>less than 3 months post-stroke for 50% of patients; more than 3 months for 50% of patients</td>
<td>age, hemisphere of stroke</td>
<td>none</td>
<td>no</td>
<td>improvement in functional status</td>
</tr>
<tr>
<td>Carroll</td>
<td>to determine the prognostic importance of age, associated illness, early recovery &amp; presence of more than one stroke</td>
<td>98 patients. Diagnoses: thrombosis, hemorrhage or embolism. 29% of patients had had previous strokes (1) 138 patients, mean age 70 years; first stroke; absence of disability before stroke (2) 21 patients with more than one stroke before admission</td>
<td>within 1 week post-stroke</td>
<td>age, diminished reflexes, pneumonia, coma, functional admission score</td>
<td>negative, negative, negative, positive</td>
<td>no</td>
<td>functional status at 1 month, 6 months, 1 year and 2 years post-stroke</td>
</tr>
<tr>
<td>Katz</td>
<td>to determine the prognostic importance of age, associated illness, early recovery &amp; presence of more than one stroke</td>
<td>736 patients</td>
<td>within 30 days post-stroke</td>
<td>age, previous stroke, presence of early neuromuscular recovery</td>
<td>negative, positive</td>
<td>yes (Katz Index)</td>
<td>functional status at 3 semi-annual intervals post-stroke</td>
</tr>
<tr>
<td>Adams</td>
<td>to examine factors influencing functional recovery</td>
<td>62 patients, mean age 64 years. Diagnoses: arteriosclerosis or embolism (cerebral hemorrhage excluded)</td>
<td>less than 24 days to more than 58 days post-stroke</td>
<td>sex, age, onset-admission interval, hemisphere of stroke</td>
<td>none, negative, negative, negative, negative</td>
<td>no</td>
<td>functional status at discharge</td>
</tr>
<tr>
<td>Stern</td>
<td>to identify factors which influence outcome of stroke rehabilitation</td>
<td>62 patients, mean age 64 years. Diagnoses: arteriosclerosis or embolism (cerebral hemorrhage excluded)</td>
<td>less than 24 days to more than 58 days post-stroke</td>
<td>severity of hemiparesis, hemisensory loss, onset-admission interval</td>
<td>negative, negative</td>
<td>yes (Kenny Self-care evaluation)</td>
<td>improvement in functional status</td>
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<tr>
<td>Lehmann¹⁹</td>
<td>to identify predictors of functional outcome</td>
<td>114 patients</td>
<td>after admission to a rehab. centre; time post-stroke not noted</td>
<td>age, functional status on admission, WAIS, size &amp; severity of lesion, presence of heart failure &amp; arteriosclerosis, education</td>
<td>negative with discharge function; no association with improvement in function</td>
<td>no</td>
<td>improvement in functional status and function on discharge</td>
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<td>none with improvement positive with discharge function negative with discharge function negative with discharge function</td>
<td>positive (r = .17) with functional improvement</td>
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<tr>
<td>Feigenson¹⁷</td>
<td>to examine factors influencing outcome of stroke rehabilitation</td>
<td>248 patients, mean age 67 years.</td>
<td>average, 38 days post-stroke</td>
<td>severity of hemipareses, age, onset-admission interval, hemisensory deficit, dysphasia, severe perceptual dysfunction (dementia, neglect, visuospatial), homonymous hemianopsia</td>
<td>negative</td>
<td>no</td>
<td>functional status on discharge</td>
</tr>
<tr>
<td>Granger³¹</td>
<td>to measure outcomes of care for stroke patients</td>
<td>164 patients</td>
<td>time post-stroke not noted</td>
<td>functional status on admission</td>
<td>positive</td>
<td>yes (Barthel Index)</td>
<td>functional status on discharge</td>
</tr>
<tr>
<td>Waltimo²</td>
<td>to document functional recovery in patients with occlusion of internal carotid artery</td>
<td>155 patients, median age 53 years.</td>
<td>within several days post-stroke</td>
<td>age</td>
<td>negative</td>
<td>no</td>
<td>functional status after discharge (mean follow up time 53 months)</td>
</tr>
<tr>
<td>Kaste et al⁷</td>
<td>to document functional recovery in patients with occlusion of middle cerebral artery</td>
<td>78 patients, mean age 44 years.</td>
<td>within several days post-stroke</td>
<td>sex, age, location of MCA occlusion</td>
<td>none negative</td>
<td>no</td>
<td>functional status after discharge (mean follow up time 30 months)</td>
</tr>
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<tr>
<td>Drake</td>
<td>to compare changes in patient outcome across 3 hospitals</td>
<td>455 patients, mean age 70 years. Diagnoses: CVA not specified 52%, arteriosclerosis 29%, embolism 2%, cerebral hemorrhage 13%, SAH 16%, other 3%</td>
<td>within 5 days post-stroke</td>
<td>sex, functional status on admission</td>
<td>none positive</td>
<td>no</td>
<td>functional status on discharge</td>
</tr>
<tr>
<td>Anderson</td>
<td>to determine predictors of long-term functional improvement in a rehabilitation program</td>
<td>233 patients</td>
<td>time post-stroke not noted</td>
<td>time since onset of stroke, age, urinary incontinence, bowel incontinence, previous stroke, Block Design subtest of WAIS, Object Assembly subtest of WAIS, long period of unconsciousness at time of stroke</td>
<td>negative</td>
<td>yes (Kenny Self-care Evaluation)</td>
<td>improvement in functional status measured at discharge &amp; 3 month follow-up</td>
</tr>
<tr>
<td>Gordon</td>
<td>to identify predictors of outcome with stroke patients</td>
<td>105 patients. Diagnoses: thrombosis 75%, embolism 14%, hemorrhage 11%</td>
<td>mean of 37 days post-stroke</td>
<td>age, presence of bowel &amp; bladder control at admission, marital status, functional status on admission, sex, previous stroke, location of stroke</td>
<td>negative, none</td>
<td>no</td>
<td>functional status on discharge</td>
</tr>
<tr>
<td>Prescott</td>
<td>to determine predictive value of mental, sensory &amp; communication tests</td>
<td>149 patients, mean age 72-79 years. Patients unconscious at onset of stroke or able to walk independently after stroke excluded</td>
<td>within 1 week post-stroke</td>
<td>upper limb function, postural function, proprioception</td>
<td>positive, positive, positive</td>
<td>no</td>
<td>functional status on discharge or 16 weeks post-stroke</td>
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<tr>
<td>Jimenez²³</td>
<td>to identify predictors of outcome with stroke patients</td>
<td>105 patients. Diagnoses: thrombosis 75%, embolism 14%, hemorrhage 11%</td>
<td>mean of 37 days post-stroke</td>
<td>age, presence of bowel &amp; bladder control on admission, marital status, functional status on admission, sex, previous stroke location of stroke, presence of bowel &amp; bladder control on admission</td>
<td>negative, positive</td>
<td>no</td>
<td>improvement in functional status</td>
</tr>
<tr>
<td>Andrews²³</td>
<td>to determine whether side of stroke influenced outcome of stroke</td>
<td>135 patients. Conscious level disturbed at onset of stroke in 30% of patients</td>
<td>within 2-3 weeks post-stroke</td>
<td>hemisphere of stroke</td>
<td>none</td>
<td>no</td>
<td>functional status at 6 week intervals post stroke (up to 1 year)</td>
</tr>
<tr>
<td>Mills²⁴</td>
<td>to examine functional differences in patients with left &amp; right CVA</td>
<td>102 patients, mean age 69 years. CVA in middle cerebral artery. Patients with previous CVA or other medical problems excluded</td>
<td>2-4 weeks post-stroke</td>
<td>hemisphere of stroke</td>
<td>none</td>
<td>no</td>
<td>functional status on discharge</td>
</tr>
<tr>
<td>Denes²⁵</td>
<td>to examine functional outcome of left &amp; right CVA patients</td>
<td>48 patients, mean age 61 years. Diagnoses: hemorrhage or ischaemia</td>
<td>within 2 weeks post-stroke</td>
<td>hemisphere of stroke</td>
<td>patients with left-sided lesions improved significantly more than those with right-sided lesions</td>
<td>no</td>
<td>functional improvement 6 months post-stroke</td>
</tr>
<tr>
<td>Kaplan²¹</td>
<td>to investigate the influence of visuo-spatial deficits on functional status after right CVA</td>
<td>34 patients with right CVA, mean age 67 years. No previous stroke, right handed</td>
<td>4-5 weeks post-stroke</td>
<td>severity of hemiparesis, hemianopia, presence of tactile extinction, visuo-spatial tests, Rey Figure, Block Design, Embedded Figures Test, Embedded Figures Test</td>
<td>negative, negative</td>
<td>yes (Kenny Self-care Evaluation)</td>
<td>functional status at discharge &amp; improvement in functional status</td>
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<tr>
<td>Kottila</td>
<td>to analyze the influence of neurological, neuropsychological &amp; premorbid factors on outcomes at specific points in time</td>
<td>154 patients, mean age 61 years. Diagnoses: subarachnoid hemorrhage, intracranial hemorrhage, infarction</td>
<td>within 3 days post-stroke</td>
<td>age, severity of hemiparesis, lowered level of consciousness at onset, impairment of intelligence, visuoperceptual deficits, depression &amp; emotional lability, hemisphere of stroke, type of stroke</td>
<td>none with function at 3 months, negative with function at 12 months</td>
<td>no</td>
<td>functional status 3 &amp; 12 months post-stroke</td>
</tr>
<tr>
<td>Dove</td>
<td>to determine which variables are most important in terms of functional outcome</td>
<td>97 patients, mean age 62.7 years. Patients with TIA, brainstem stroke, intracerebral hematoma, previous stroke, SAH excluded</td>
<td>within 4 days post-stroke</td>
<td>age, lesion size, severity of lesion, location of lesion, functional status on admission</td>
<td>negative; explained 64% of variance</td>
<td>no</td>
<td>functional status on discharge</td>
</tr>
<tr>
<td>Hertanu</td>
<td>to examine the predictive value of lesion size &amp; location as demonstrated on brain computerized tomography in functional recovery</td>
<td>41 patients, mean age 69 years</td>
<td>within 6 days post-stroke</td>
<td>age, lesion size, severity of lesion, location of lesion, functional status on admission</td>
<td>negative; explained 64% of variance</td>
<td>yes (Barthel Index)</td>
<td>functional status on discharge</td>
</tr>
<tr>
<td>Wade</td>
<td>to identify factors of prognostic importance in stroke recovery</td>
<td>45 patients, mean age 68.7 years</td>
<td>mean, 4 days post-stroke</td>
<td>urinary incontinence, 10 days post-stroke, age, proprioceptive loss in thumb, severity of hemiparesis</td>
<td>negative; explained 64% of variance</td>
<td>no</td>
<td>functional status 13 weeks post-stroke</td>
</tr>
<tr>
<td>Adler</td>
<td>to determine whether age is a significant predictor of outcome in stroke patients</td>
<td>180 patients</td>
<td>after admission to rehab. centre; time post-stroke not noted</td>
<td>age</td>
<td>none</td>
<td>no</td>
<td>improvement in functional status</td>
</tr>
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<tr>
<td>Novack²⁷</td>
<td>to examine relationship between time since onset of stroke before admission to a rehab. facility and outcome</td>
<td>687 patients, mean age 62.7 years. Patients with previous stroke excluded</td>
<td>mean of 74–75 days post-stroke</td>
<td>onset-admission interval</td>
<td>negative with transfers, &amp; self-care (household activities) none with self-care (dressing, feeding, hygiene)</td>
<td>no</td>
<td>functional status on discharge</td>
</tr>
<tr>
<td>Wade¹³</td>
<td>to predict functional status at 6 months post-stroke</td>
<td>83 patients, mean age 66.5 years</td>
<td>within 3 weeks post-stroke</td>
<td>age, hemianopia, urinary incontinence, motor deficit, affected arm, sitting balance, age, hemianopia, initial Barthel score</td>
<td>negative negative negative negative</td>
<td>yes (Barthel Index)</td>
<td>functional status 6 months post-stroke</td>
</tr>
<tr>
<td>Ahlsio¹⁴</td>
<td>to examine how quality of life of stroke survivors is influenced by disability and emotional factors</td>
<td>162 patients</td>
<td>within 90 days post-stroke</td>
<td>hemisphere of stroke, aphasia, spatial deficit</td>
<td>none none none negative correlation at discharge no correlation at 6 months post-stroke</td>
<td>yes (Katz Index)</td>
<td>functional status at 1, 3, 6, 12, 18, 24 &amp; 36 months post-stroke</td>
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<tr>
<td>Ahlsio¹⁴</td>
<td></td>
<td>96 patients, mean age 71 years. Diagnoses: hemorrhage 5%, thrombosis 60%, embolism 11%, TIA 22%, unspecified 2%. 20% of patients had previously had a stroke or TIA</td>
<td>within 1 week post-stroke</td>
<td>age, functional status on admission</td>
<td>negative positive</td>
<td>yes (Katz Index)</td>
<td>functional status at intervals post-stroke (up to 2 years)</td>
</tr>
</tbody>
</table>
Urinary Incontinence

Urinary incontinence on admission is an adverse prognostic factor for functional outcome.8, 9, 12, 13, 15, 19

Bowel Incontinence

Bowel incontinence on admission is an unfavourable sign; patients with bowel incontinence improve less or have lower functional abilities on discharge than those who possess bowel control.8, 9, 15

Hemisphere of Stroke

There is general agreement10, 15, 16, 22 that there is no relationship between hemisphere of stroke and function on discharge. Two exceptions are studies by Denes25 who found that patients with left CVAs improved significantly more than those with right CVAs, and Adams2 who reports that men (but not women) with left CVAs had significantly better function on discharge than those with right CVAs.

Interval Between Onset of Stroke and Hospital Admission

Six studies2, 5, 8, 15, 17, 26 report that the longer the interval between the onset of the CVA and hospital admission, the less favourable the functional outcome. Novack26 found that certain functional activities (ambulation and transfers) were adversely affected by delay in admission, while others (dressing, feeding, hygiene) were not.

Three of the 6 studies which found the longer interval between the onset of the CVA and admission, the less favourable the outcome, measured improvement over time.8, 15, 26 As stroke recovery occurs most rapidly in the early months, it is to be expected that those who are studied earlier will show more change in functional status. Findings of Wade13 illustrate this; he found no correlation between delay in admission and functional status six months post-stroke, but a negative correlation (r = —0.24) between delay in admission and improvement occurring between the initial and six month functional testing. Thus the apparent relationship between early admission and improvement may well reflect the pattern of stroke recovery rather than indicate that early treatment is beneficial. However, this does not explain the findings of the 3 studies2, 5, 17 whose outcome measure was discharge functional status, and which report negative correlations between this measure and delay in admission. A conclusive statement about the importance of early admission cannot be made. Future studies should include this variable, and measure functional status at set intervals post-stroke, as did Wade.13 This will allow comparison of functional status at set times post-stroke, as well as functional improvement for individuals admitted at various times post-stroke, and eliminate problems associated with differing lengths of hospital stay.

Severity of Paralysis

Three studies8, 17, 26 report that the more severe the hemiparesis on admission, the less favourable the functional outcome. Wade,13 on the other hand, reports no correlation between severity of hemiparesis and functional status 13 months post-stroke. Kaplan24 found the severity of hemiparesis on admission to have a significant negative correlation with discharge self-care status (r = —.43, p < .05), but to have only a .02 correlation with change in self-care status.

Findings regarding the severity of paralysis as a prognostic indicator are thus ambiguous, and are made even more difficult to interpret because all studies measured patient outcome in different ways: improvement in functional status was used by Stern,26 function on discharge by Feigenson,17 functional status at 3 and 12 months by Kotila,10 and functional status at 13 months post-stroke by Wade.12 As will be shown in the critique of literature, these are all very different measures.

Visuo-Spatial Deficits

The presence of visuo-spatial deficits is an adverse prognostic indicator of functional outcome.8, 17, 22, 23, 28-30

Functional Admission Score

Whereas a functional admission score has been found to be positively correlated with functional outcome in most studies,1, 11, 13-15, 20, 31 two studies4, 19 report no correlation between these variables. Six of the 7 studies which report a positive correlation between the two variables use function on discharge, or function at set intervals post-stroke, as the outcome measure. Improvement in function was the outcome measure in the two studies reporting no correlation. As noted earlier, function on discharge and improvement in function measure different factors. A correlation of .50 between functional improvement and function on discharge is reported in one study,23 and a fairly strong negative correlation (r = —.75) in another (Jongbloed and Collins, unpublished). The latter study reports a correlation of .72 between functional admission and function on discharge, and a negative correlation (r = —.76) between functional admission score and improvement in function.

Thus functional admission score appears to have a fairly strong positive correlation with function on discharge, but its relationship with improvement in function is less clear. It may be that the nature of this relationship depends on the severity of patients included in the study: moderately affected patients frequently show more improvement than mildly and severely affected individuals.

Critique of the Literature

Much of the clinical data reviewed in this paper is difficult to interpret because the initial presentation is incomplete. Several studies do not identify patient diagnoses, age, time between onset of stroke, and observations or size of correlations between patient characteristics and functional outcome. Studies can also not readily be compared because there is little uniformity in diagnosis, age of sample, criterion by which outcome is assessed, and measuring instrument used. The
ways in which these differences could have affected study findings are examined below.

Patient Sample

Cerebrovascular accidents are usually categorized as resulting from hemorrhage, thrombosis or embolism. Rate of recovery of function is influenced by etiology. The post-hemorrhagic patient, if he survives, is very ill and may have bilateral signs initially, but recovery continues over a long time as the edema subsides. On the other hand, the most significant recovery in a post-occlusion stroke patient occurs within 3 months and plateaus at 6 months. There are considerable differences in etiology of patients included in the studies reviewed (see table 1). Furthermore, some studies excluded patients with mild and severe strokes and included only those who were moderately affected. Bourestom found that predictors of functional outcome differed according to initial severity of stroke, i.e. predictors of functional outcome for mildly affected stroke patients differed from predictors for severely affected patients. Substantial differences between patient samples mean that predictor variables found important for one sample would not necessarily be accurate for another.

Time of Initial Assessments

The first 4 weeks following a stroke is a time when many patients die, but it is also a period when others improve remarkably. Prescott has demonstrated that predictive accuracy changes at different times for groups with various prognoses. Using an equation derived from multiple regression, he predicted patient function at 4, 8 and 12 weeks post-stroke and also noted actual function at these times. The accuracy of prediction in the good prognosis group was found to be good in the early stages after a stroke, but once patients had been in hospital for 2 months, the accuracy of prediction for this group deteriorated. Predictive accuracy in the poor prognosis group, on the other hand, was not as sensitive to the passage of time; the chance of a patient regaining independence was remote if he was still in the poor prognosis group more than a month after the stroke.

There is considerable variation in timing of initial patient assessments among studies; in 11 studies patient assessments were conducted within a week post-stroke, in 7 this was done between 2 and 4 weeks post-stroke, in 9 studies it was done between 5 and 13 weeks, while 6 studies do not note when assessments were done. There is also variation in timing of initial patient assessments within studies. These differences could not only account for some of the variation in findings among studies but also make comparison between studies difficult.

Criteria by which Outcome is Measured

Some studies used improvement in functional status as the outcome measure, others used functional status on discharge, and a few used function at set times post-stroke. However, variables which predict improvement in functional status differ from variables which predict functional status on discharge. In Kaplan's study, predictors of discharge function were found to be the Rey Figure Test, the Embedded Figures Test, Block Design, hemiparesis and hemianopia, whereas predictors of improvement in function were hemianopia, length of hospital stay, the Embedded Figures Test and extinction. Similarly, Lehmann found that age correlated .30 with discharge function, but had no correlation with improvement in function; and Wade reports no correlation between delay in admission and improvement, but a -.24 correlation between delay in admission and functional status 6 months post-stroke.

A study by Wade illustrates the hazards of using events such as discharge rather than time post-stroke as markers in measuring stroke recovery. Patients with left CVAs were found to have longer hospital stays and higher discharge functional scores than those with right CVAs, leading to the apparent conclusion that they had made a better recovery. However, there was no difference between these two groups at any fixed time post-stroke. Future studies should measure patient function at set times post-stroke in order to avoid these pitfalls.

Measurement of Functional Outcome

Comparison among studies is difficult unless the same measure of function is used. Most investigators used measuring instruments that had been developed at their particular institutions. Some included bowel and bladder function, walking and transfers, others did not, and many failed to specify what activities were included in their measures. Rating systems also varied. Although there are several functional indices whose reliability and validity is well documented, 63 percent of the studies measured function with instruments of no reported reliability or validity, raising serious questions about the validity of their findings. It is strongly recommended that instruments whose reliability and validity is well established be utilized in future studies. Inadequate measurement should no longer be tolerated.

Data Analysis

As noted earlier, the goals of studies differed and consequently their analysis. Some investigated the prognostic value of a single variable, others identified which variables among many were the most important predictors of functional outcome. Some of the recent studies used multiple or stepwise regression to analyze data, and report the amount of variance in functional outcome accounted for by different variables, thus providing information regarding the relative importance of various predictor variables. However, in many studies the presentation of data does not go beyond enumeration. Others report correlation coefficients but not their statistical significance. The regular use of established methods of presenting and analyzing data would enhance understanding of the clinical problem.
Implications for Research

There have been two general approaches to predicting functional outcome after stroke. The first has involved examining the relationship between a single factor (e.g., age) and outcome. This method has identified many variables that relate individually to functional outcome, but none has shown a correlation with outcome high enough to allow precise prediction of individual outcome.

The second approach has been to identify a group of variables which collectively relate to the outcome, using techniques such as multiple and stepwise regression. Again, however, no group of predictors has been found accurate enough to predict gain in the individual patient. A group of predictors can only be used to describe in general terms those who would do better and worse. Also, the initial variables identified (and their relative importance) have varied from study to study, and no clear-cut consensus has emerged.

Additional limitations of study findings are the lack of cross-validation studies, and the fact that samples studied were not necessarily representative of all stroke patients. Cross-validation consists of ascertaining that an empirically developed predictor measure works when applied to a new sample. Unless a study is replicated at least once with similar results, little confidence can be placed in the predictor measure. Cross-validation was conducted by only 4 of the 33 studies. However, a cross-validation study conducted at the same institution as the initial study is insufficient evidence that a predictor will work at other centres. Samples of patients in particular centres are not necessarily representative of all stroke patients. Unless the sample used for cross-validation is representative of the population to which the predictor measure is to be applied in the future, the validity of the predictor is questionable. Predictor measures developed by researchers in any one institution thus have limited value; and the development of valid predictors will require cooperative research among investigators in many treatment centres.

This paper reviewed only studies which used function as the outcome measure. Other outcome measures (survival, discharge disposition, length of stay) are each associated with a unique group of predictor variables. Consequently, the likelihood of deriving an equation which would predict outcome in general is small. Future research should identify variables which are consistently associated with several outcome measures.

The complexity of prediction with the stroke population is clear. However, even if a valid prognostic index could be derived, how should this be used in clinical situations? Should resources be focused on patients with good prognoses, or would they improve without rehabilitation programs? Should increased resources be channeled to patients with poor prognoses? Are moderately affected patients more likely to benefit from an intensive rehabilitation program than severely or minimally affected patients? Some of these questions are beginning to receive attention in the literature.

Summary

A review of 33 studies which identify patient characteristics that predict functional recovery indicates that a previous stroke, older age, urinary and bowel incontinence and visuo-spatial deficits are adverse prognostic indicators of function. There is no relationship between sex and hemisphere of stroke and functional outcome. Functional admission score has a positive correlation with discharge functional status, but its relationship with improvement is unclear. The prognostic value of severity of paralysis and onset-admission delay requires additional research.

Differences among patient samples mean that predictor variables identified with one sample will not necessarily be accurate for other samples. Studies conducted across treatment centres would help ensure that the sample is representative of the population to which the predictor measure is to be applied in the future.

Many studies measured function on discharge while others measured improvement in function. However, predictors for each of these outcomes differ, making comparison among studies difficult. Since length of hospital stay varies enormously both among hospitals and among patients in a single hospital, measurement of function on discharge can result in faulty conclusions regarding the prognostic value of a variable. Future studies should measure function at set times post-stroke.

Even though functional scales exist whose reliability and validity is well established, 63 percent of the studies used scales whose reliability and validity are unknown. Poor measurement can invalidate any scientific investigation and should not be tolerated.

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doi: 10.1161/01.STR.17.4.765

*Stroke* is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Copyright © 1986 American Heart Association, Inc. All rights reserved.
Print ISSN: 0039-2499. Online ISSN: 1524-4628

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/17/4/765

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