Diagnostic Accuracy of the Barthel Index for Measuring Activities of Daily Living Outcome After Ischemic Hemispheric Stroke

Does Early Poststroke Timing of Assessment Matter?

Gert Kwakkel, PhD; Janne M. Veerbeek, MSc; Barbara C. Harmeling-van der Wel; Erwin van Wegen, PhD; Boudewijn J. Kollen, PhD; on behalf of the Early Prediction of functional Outcome after Stroke (EPOS) Investigators

**Background and Purpose**—This study investigated the diagnostic accuracy of the Barthel Index (BI) in 206 stroke patients, measured within 72 hours, for activities of daily living at 6 months and determined whether the timing of BI assessment during the first days affects the accuracy of predicting activities of daily living outcome at 6 months.

**Methods**—Receiver operating characteristic curves were constructed to determine the area under the curve and optimal cutoff points for BI at Days 2, 5, and 9. OR, sensitivity, specificity, positive predictive value, and negative predictive value were calculated to predict BI outcome.

**Results**—The area under the curve ranged from 0.785 on Day 2 to 0.837 and 0.848 on Days 5 and 9. Comparison of the receiver operating characteristic curves showed that the area under the curve was significantly different between Days 2 and 5 (P<0.001) and between Days 2 and 9 (P<0.001). No significant difference was found between Days 5 and 9 (P=0.08). Using a BI cutoff score of 7, the positive predictive value gradually increased from 0.696 on Day 2 to 0.817 on Day 2 to 0.864 on Day 9, whereas negative predictive value declined from 0.778 on Day 2 to 0.613 on Day 9.

**Conclusions**—Assessment of the BI early poststroke showed good discriminative properties for final outcome of BI at 6 months. However, Day 5 proved to be the earliest time for making an optimal prediction of final outcome of activities of daily living. The BI should be measured at the end of the first week in hospital-based stroke units for early rehabilitation management. (*Stroke*. 2011;42:342-346.)

**Key Words:** ADL ■ Barthel Index ■ stroke prognosis ■ stroke units

A number of prospective epidemiological studies in the Western countries found that approximately 60% of all stroke victims will regain independency in basic activities of daily living (ADL) within 6 months poststroke.1 According to the American Heart Association, approximately 14% of these stroke survivors achieve full recovery in their basic ADLs, between 25% and 50% require at least some assistance in ADLs, and approximately half experience severe long-term dependency.2 In particular, forced by rising healthcare costs, there is a growing need for early accurate prediction of outcome after stroke to (1) set realistic and attainable treatment goals; (2) inform clients and their relatives properly; (3) facilitate discharge planning; and (4) anticipate possible consequences such as implementing home adjustments and address the need for community support. Unfortunately, there is no consensus on which measurements should be used in stroke units nor about the most appropriate poststroke timing to perform these assessments.3,4 A commonly used measurement tool to assess ADL independency in stroke units is the Barthel Index (BI).5 The BI scale measures patients’ actual performance in basic ADLs by inquiry and/or observation and contains 10 items, which are scored using arbitrary
weights (5, 10, or 15) to arrive at a total scale range of 0 to 100 or alternatively uses 0, 1, 2, or 3 weighted item scores on a 0 to 20 scale.\(^6\)\(^\text{–}^8\) The instrument is easy to administer, does not need formal training or certificate programs,\(^5\) and the 0 to 20 scale version has been shown to be reliable\(^6\) and concurrently valid when compared with the motor part of the Functional Independence Measure\(^8\) and the modified Rankin Scale (mRS).\(^4\)\(^\text{–}^9\)\(^\text{–}^11\) Finally, the BI has demonstrated excellent discriminative properties in organized inpatient trials.\(^1\) Moreover, a number of prospective studies have shown that the severity of disability according to the BI recorded at 5 days poststroke, even when dichotomized,\(^1\)\(^3\)\(^\text{–}^15\) shows a highly prognostic accuracy for death\(^1\) or dependency as a final outcome.\(^1\)\(^\text{–}^1^3\)\(^\text{–}^1^5\) As a consequence, the BI has been recommended to be used for the development of predictive risk models to estimate final outcome for those patients who were lost in trials.\(^1\)\(^0\)

Despite the growing consensus that the BI should be implemented as a standardized tool of measuring disability in acute (multicenter) trials\(^1\)\(^1\)\(^1\) and should be used preferably in a repetitive way to assess improvement in patients over time,\(^3\) there is little consensus about the optimal timing for assessing the BI in hospital-based stroke units as a tool for monitoring severity of disability and to predict the final outcome of ADLs after stroke. Moreover, in prospective longitudinal studies, the optimal timing of assessment early poststroke is an important factor that determines the accuracy of prediction.\(^1\)\(^6\)

The first objective of the present study was to investigate the predictive value of BI measured within 72 hours for outcome of basic ADLs assessed at 6 months poststroke. The second aim was to determine the optimal poststroke timing of BI assessment in hospital stroke units for the most accurate prediction of final outcome of ADLs at 6 months poststroke.

**Subjects and Methods**

**Design**

The Early Prediction of functional Outcome after Stroke (EPOS) study is a prospective cohort study that applies an intensive repeated-measurements design starting within 72 hours after stroke onset. The diagnosis of stroke was based on the definition by the World Health Organization. Two hundred forty-six patients were recruited for the EPOS study in 34 months. Patients were recruited from 9 hospital-based stroke units in The Netherlands (ie, Erasmus MC Rotterdam; UMC Utrecht; VU University Medical Center Amsterdam; AMC Amsterdam; UMC St Radboud Nijmegen; LUMC Leiden; Amphia Hospital Breda; Franciscus Hospital Roosendaal; and Diaconessen Hospital Leiden). The EPOS test battery was applied within 72 hours poststroke, even when dichotomized,\(^1\)\(^3\)\(^\text{–}^1^5\) showed a highly prognostic accuracy for death\(^1\) or dependency as a final outcome.\(^1\)\(^\text{–}^1^3\)\(^\text{–}^1^5\) As a consequence, the BI has been recommended to be used for the development of predictive risk models to estimate final outcome for those patients who were lost in trials.\(^1\)\(^0\)

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collected at 5 and 9 days poststroke. Finally, 2-way contingency tables were used to calculate sensitivity, specificity, and negative and positive predictive values, including their 95% CIs, for each model within 72 hours poststroke and on Days 5 and 9 poststroke. All analyses were 2-tailed using a critical probability value for significance of 0.05 and performed with SPSS Version 15.

**Results**

Forty of 246 patients were lost to follow-up due to death (N=23), refusal for assessment at 6 months (N=3), recurrent stroke (N=5), or other reasons (N=9). In addition, assessments of 14 patients were missing at T1 and 22 at T2. In total, 206 patients were included in analysis representing a particular segment from within the total stroke population. Table 1 presents the main characteristics of the remaining 206 patients. The candidate determinants were measured on a mean (SD) 2.18 (1.19), 5.50 (1.52), and 9.29 (4.89) days poststroke.

The average age of patients in this cohort was 66.3 (14.0) years and 95 of the patients were male. Eighty-eight subjects had a stroke in the left hemisphere. According to the Bamford classification, 96 patients were diagnosed with lacunar circulation infarcts, 42 with total anterior circulation infarcts, and 68 patients had a partial anterior circulation infarct. The median BI score on Days 2 was 7 points (interquartile range, 3 to 12), whereas the median mRS was 4 points (interquartile range, 3.75 to 5). At 6 months, BI had a median of 19 points (interquartile range, 16.75 to 20), whereas 60.7% of the 206 patients showed full independency on the BI.

The Figure shows the ROC analysis for BI scores on Days 2, 5, and 9. The AUC ranged from 0.785 for Day 2 to 0.848 for Day 5 (z=0.908). Comparison of the 3 derived ROC curves showed that the AUC was significantly different between Day 2 and Day 5 (z=3.537, P<0.001) and between Day 2 and 9 (z=3.621, P<0.001). However, no significant difference was found between the AUC of the ROC curves of Days 5 and 9 (z=1.416, P=0.08). The optimal cutoff value, with the highest sensitivity and 1-specificity, was found when BI was dichotomized into ≤6 points (ie, severe disability) and ≥7 points (ie, moderate to mild disability).

Table 2 shows the numbers of true- and false-positives and negatives as well as the OR, sensitivity, specificity, positive predictive value, and negative predictive value calculated using a cutoff value of 7 points on BI in terms of predicting dichotomized BI outcome at 6 months poststroke. ORs based on a cutoff score of ≥19 points ranged from 8.013 (95% CI, 4.192 to 15.316) on Day 2 to a maximum of 10.533 (95% CI, 5.458 to 20.325) on Day 5. The positive predictive value showed a gradual increase from 0.696 (95% CI, 0.645 to 0.739) on Day 2 to 0.864 (95% CI, 0.815 to 0.905) on Day 9, whereas negative predictive value declined from 0.778 (95% CI, 0.699 to 0.844) on Day 2 to 0.613 (95% CI, 0.536 to 0.676) on Day 9. The overall accuracy for correctly predicting outcome increased from 72.8% on Day 2 to 77.2% on Day 5.

**Discussion**

The purpose of the present study was to determine the discriminative properties of the BI (Version 0–20) assessed at hospital-based stroke units within 72 hours poststroke for the outcome of ADL independency at 6 months. In addition, the optimal timing for early poststroke assessment of the BI to predict outcome of ADL at 6 months after stroke was explored. The present study demonstrated good discriminative properties of the BI on Days 2, 5, and 9 poststroke. However, it also suggests that the earliest, most optimal poststroke assessment is on Day 5. Assessment on Day 2 resulted in an increased number of false-negatives and consequently an underestimation of the final outcome of ADL, whereas assessment on Day 9 resulted in a relatively overes-
differences were found among Day 2, 5, or 9. However, our use of the Functional Independence Measure for evaluating poststroke disability. However, knowledge about the predictive value and optimal timing of assessment in hospital stroke units is lacking in the literature for other clinical useful measurement instruments such as the Functional Independence Measure and mRS.

The present study has some limitations. First, the day of the first assessment on Day 2 was selected to conform with the Dutch stroke guidelines that recommend to mobilize patients within 72 hours poststroke onset, whereas the other 2 days of assessment (ie, Days 5 and 9) were pragmatically selected based on clinical experience. Second, our model may not be applicable to patients with brain stem strokes, hemorrhagic strokes, or recurrent strokes, which have been shown to present with different recovery profiles. This finding suggests that the model should be re-investigated for case mix and preferably crossvalidated in a holdout group. Third, it should be emphasized that the BI is not suitable for measuring disability within the first 3 days poststroke. To the best of our knowledge, the present study is the first study that underscores the limitations of BI use within the first 3 days poststroke.

It should be noted that we selected the BI tool as recommended by the Dutch stroke guidelines for rehabilitation management and because it is the most commonly used disability scale for evaluating effectiveness of stroke units. The BI use is in line with our stroke guidelines for physical therapy and stroke management as well as the recommendations of the Agency for Health Care Policy and Research Post-Stroke Rehabilitation Panel. Both of these authorities recommend to use the BI and the motor component of the Functional Independence Measure for evaluating poststroke disability. However, knowledge about the predictive value and optimal timing of assessment in hospital stroke units is lacking in the literature for other clinical useful measurement instruments such as the Functional Independence Measure and mRS.

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**Figure.** Graphic presentation of ROC analyses of timing of assessment outcome of dichotomized BI (≥19) after 6 months (N=206).

**Table 2. Predictive Value of Dichotomized BI Assessed on Days 2, 5, and 9 Poststroke for BI Independency After 6 Months (N=206)**

<table>
<thead>
<tr>
<th>Assessment</th>
<th>True-Negatives, No.</th>
<th>False-Negatives, No.</th>
<th>False-Positives, No.</th>
<th>True-Positives, No.</th>
<th>OR† (95% CI)</th>
<th>Accuracy</th>
<th>Sensitivity (95% CI)</th>
<th>Specificity (95% CI)</th>
<th>PPV (95% CI)</th>
<th>NPV (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day 2</td>
<td>63</td>
<td>38</td>
<td>18</td>
<td>87</td>
<td>8.013 (4.192-15.316)</td>
<td>0.728</td>
<td>0.829 (0.768-0.879)</td>
<td>0.624 (0.560-0.677)</td>
<td>0.696 (0.645-0.739)</td>
<td>0.778 (0.699-0.844)</td>
</tr>
<tr>
<td>Day 5</td>
<td>57</td>
<td>23</td>
<td>24</td>
<td>102</td>
<td>10.533 (5.458-20.325)</td>
<td>0.772</td>
<td>0.810 (0.760-0.852)</td>
<td>0.713 (0.634-0.779)</td>
<td>0.816 (0.766-0.859)</td>
<td>0.704 (0.626-0.769)</td>
</tr>
<tr>
<td>Day 9</td>
<td>49</td>
<td>17</td>
<td>31</td>
<td>108</td>
<td>10.042 (5.082-29.842)</td>
<td>0.766</td>
<td>0.777 (0.733-0.813)</td>
<td>0.742 (0.650-0.819)</td>
<td>0.864 (0.815-0.905)</td>
<td>0.613 (0.538-0.676)</td>
</tr>
</tbody>
</table>

*aBI is 0 to 20 points.
†Using a cutoff of 7 points on BI.
PPV indicates positive predictive value; NPV, negative predictive value.
be insensitive to small changes in functional status, suffers from ceiling effects, and allows for the use of compensation strategies when the nonparetic arm is used for grooming and eating.

Sources of Funding

This study was part of the Early Prediction of Functional Outcome after stroke (EPOS) research project funded by the “Wetsenschapelijk College Fysiotherapie” (WCF; number 33368) of the Royal Dutch Society for Physical Therapy (KNGF), The Netherlands and by ZON-MW (Zorg Onderzoek Nederland grant 89000001) as a part of the EXPlaining PLasticiTy after stroke (EXPLICIT)-stroke program (www.explicit-stroke.nl). EXPLICIT is registered at The Netherlands Trial Register (NTR, www.trialregister.nl, TC 1424).

Disclosures

None.

References