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## **Diagnostic accuracy of the Barthel Index for measuring activities of daily living outcome after ischemic hemispheric stroke: does early poststroke timing of assessment matter?**

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## ABSTRACT

**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 cut-off points for BI at days 2, 5, and 9. Odds ratio, sensitivity, specificity, positive predictive value, and negative predictive value were calculated to predict BI  $\geq 19$ .

**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 cut-off score of 7, the positive predictive value gradually increased from 0.696 on day 2 to 0.826 on day 5 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.

## INTRODUCTION

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.<sup>1</sup> 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.<sup>2</sup> 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.<sup>3,4</sup> A commonly used measurement tool to assess ADL independency in stroke units is the Barthel Index (BI).<sup>5</sup> 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.<sup>6-8</sup> The instrument is easy to administer, does not need formal training or certificate programs,<sup>5</sup> and the 0 to 20 scale version has been shown to be reliable<sup>6</sup> and concurrently valid when compared with the motor part of the Functional Independence Measure<sup>9</sup> and the modified Rankin Scale (mRS).<sup>4,9-11</sup> Finally, the BI has demonstrated excellent discriminative properties in organized inpatient trials.<sup>12</sup> 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,<sup>13</sup> shows a highly prognostic accuracy for death<sup>13</sup> or dependency as a final outcome.<sup>1,13-15</sup> 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.<sup>10</sup>

Despite the growing consensus that the BI should be implemented as a standardized tool of measuring disability in acute (multicenter) trials<sup>11</sup> and should be used preferably in a repetitive way to assess improvement in patients over time,<sup>5</sup> 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.<sup>16</sup>

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 (i.e. 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 after stroke and reassessed on days 5 and 9, whereas final outcome was assessed at 6 months after stroke onset.<sup>17</sup> All measurements were performed by 24 trained physical therapists working at the stroke unit of each participating center. Patients recruited for the EPOS study received usual rehabilitation care according to the Dutch Clinical Practice Guideline for physical therapy in patients with stroke.<sup>18</sup> The EPOS research protocol was approved by the local ethical review boards of the participating hospitals.

### **Subjects**

Participants of the EPOS study had to meet the following inclusion criteria: (1) subjects were diagnosed with a first-ever ischemic stroke in one hemisphere; (2) type and localization of stroke were determined by a neurologist and intracranial hemorrhage was ruled out by CT or MRI scan; (3) subjects had a monoparesis or hemiparesis within the first 72 hours after stroke; (4) subjects either did not receive recombinant Tissue Plasminogen Activator or administration of recombinant Tissue Plasminogen Activator did not result in full recovery within the first 3 days; (5) subjects had not had disability before their admission to the stroke unit conforming to a premorbid BI  $\geq 19$ ; (6) subjects were  $\geq 18$  years; and (7) subjects were able to understand instructions and to provide verbal or written informed consent to participate.

### Outcome variable

The level of ADL dependency 6 months after stroke was assessed by the BI.<sup>6,7</sup> The BI is composed of 10 items with varying weights. Two items regarding personal toilet (wash face, comb hair, shave, and clean teeth) and bathing are evaluated with a 2-score scale (0, 1 points); 6 items regarding feeding, getting onto and off the toilet, ascending and descending stairs, dressing, controlling bowels, and controlling bladder are scored on a 3-point scale (0, 1, 2 points); whereas 2 items regarding moving from a wheelchair to bed and returning and walking on a level surface are evaluated on a 4-point scale (0, 1, 2, 3 points). The BI is a cumulative score calculated by totaling all individual item scores with a maximum score of 20 points. In line with the Cochrane Stroke Unit Trialists, patients with scores  $\geq 19$  were classified as independent for basic ADL and the others as ADL-dependent.<sup>12</sup>

### Independent variables

Baseline characteristics were assessed 72 hours after stroke and included: (1) age; (2) gender; (3) type of stroke (according to the Bamford Oxford Community Stroke Project classification);<sup>19</sup> (4) number of days between the stroke and first assessment; (5) left or right hemispheric stroke; (6) urinary incontinence (bladder item of BI); (7) muscle strength and synergism of upper and lower limb paresis (Motricity Index and Fugl-Meyer Assessment motor score, respectively); (8) comorbidity (Cumulative Illness Rating Scale at baseline);<sup>20</sup> (9) mRS; (10) the 15-item version of the National Institutes of Health Stroke Scale;<sup>21,22</sup> and (11) the BI measured within 72 hours and on days 5 and 9 poststroke. Finally, Functional Ambulation Categories<sup>23</sup> and the Action Research Arm test<sup>24</sup> at baseline are presented descriptively.

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### Procedure

The research protocol started within 72 hours after stroke onset, and follow-up assessments took place after 5 and 9 days at each hospital stroke unit. The final measurement, scheduled at 6 months poststroke, was performed at the residence (i.e. home, nursing home, or rehabilitation center) or at the outpatient clinic of the hospital. All assessors in each stroke unit had familiarized themselves with the EPOS test battery before the start of the EPOS study. Despite their experience, all assessors in participating hospitals and nursing homes were trained to implement the EPOS test battery in a 1-day (8-hour) course.

## Data analyses

On the basis of sensitivity/1-specificity and maximum area (AUC) under the receiver operating characteristic (ROC) curve, the optimal dichotomization of BI was estimated for each assessment day to predict the dichotomized (i.e.  $\geq 19$  points) outcome of BI at 6 months.

In case of a missing value at the second or third assessment, the last observation was carried forward. The ROC curves of 3 models were graphically displayed and tested to assess if the AUC at day 2 was significantly different from that of days 5 and 9 and if AUC of day 5 differed significantly from day 9. For each comparison between 2 ROC curves, a z-statistic was calculated by the equation:  $z = \frac{AUC_1 - AUC_2}{\sqrt{(SE_1^2 + SE_2^2 - 2rSE_1SE_2)}}$  with  $r$  representing the Pearson product moment correlation coefficient between the 2 models.<sup>25</sup> The calculated z-statistic was evaluated to be significant if  $z \geq 1.96$ . Subsequently, on the basis of the optimal cut-off score for the first BI measurement <72 hours poststroke, a bivariable logistic regression analysis was performed between initial BI and ADL independency on the BI (i.e.  $\geq 19$  points) at 6 months to estimate the odds ratio (OR) with 95% confidence interval (CI). The same analysis was repeated for the data collected at 5 and 9 days poststroke. Finally, 2-way contingency tables were used to calculate sensitivity, specificity, and negative predictive values (NPV) and positive predictive values (PPV), 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 3.1 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 a lacunar circulation infarct, 68 with a partial anterior circulation infarct, and 42 patients had a total anterior circulation infarct. The median BI score on day 2 was 7 points (interquartile range, 3–12), whereas the median mRS was 4 points (interquartile range,

3.75–5). At 6 months, the BI had a median of 19 points (interquartile range, 16.75–20), whereas 60.7% of the 206 patients showed full independency on the BI.

**Table 3.1** Patient characteristics within 72 hours after stroke

Patient characteristics	Total
N	206
Gender, male/female	111/95
Mean (SD) age, years	66.29 (14.02)
Hemisphere of stroke, right/left	88/118
rTPA, yes/no	55/151
Mean (SD) BMI	26 (4.51)
Mean (SD) time between stroke onset and	
First assessment, days	2.18 (1.19)
Second assessment, days†	5.50 (1.52)
Third assessment, days‡	9.29 (4.89)
Type of stroke (Bamford)	
LACI	96
PACI	68
TACI	42
NIHSS*	8 (4–14)
Cognitive disturbance	
Inattention, N (%)	88 (42.7)
Disorientation, N (%)	50 (24.3)
Impairments of vision	
Hemianopsia, N (%)	62 (30.1)
Deviation conjugee, N (%)	54 (26.2)
Sensory loss, N (%)	125 (60.1)
TCT (0–100)*	74 (36.25–100)
MI arm (0–100)*	39 (0–76)
MI leg (0–100)*	53 (22.75–76.25)
FMA arm (0–66)*	20 (4–53)
FMA leg (0–34)*	20.5 (9–28)
FAC (0–5)*	1 (0–3)
ARAT (0–57)*	1.5 (0–37)
BI (0–20)*	7 (3–12)
BI urinary incontinence, N (%)	108 (52.4)
mRS*	4 (3.75–5.00)

\*Median values (interquartile ranges).

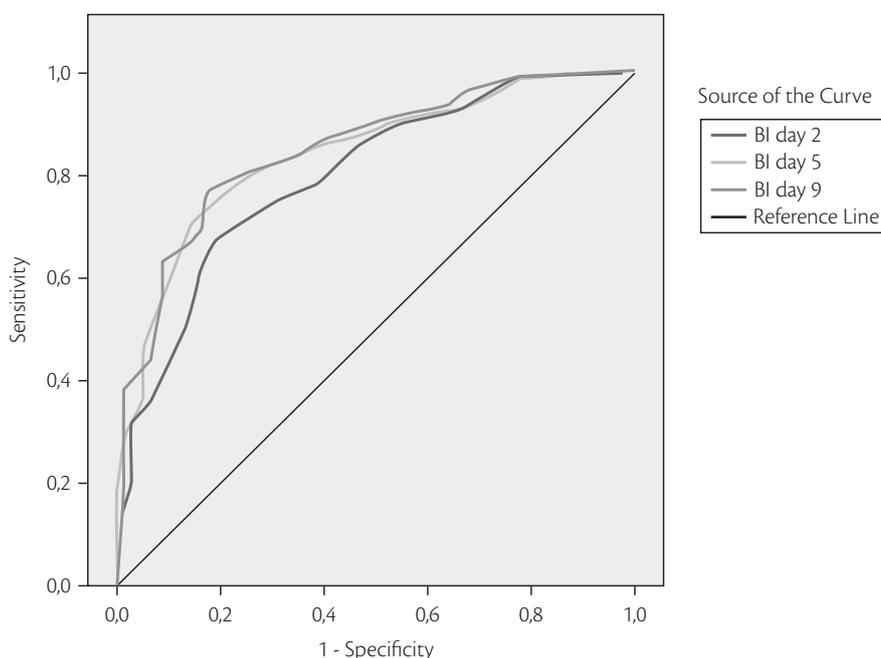
†Fourteen missing values.

‡Twenty-two missing values.

ARAT, Action Research Arm Test; BI, Barthel Index; BMI, Body Mass Index; FAC, Functional Ambulation Categories; FMA, Fugl-Meyer Assessment; LACI, Lacunar Anterior Circulation Infarcts; MI, Motricity Index; mRS, modified Rankin Scale; PACI, Partial Anterior Circulation Infarcts; rTPA, recombinant Tissue Plasminogen Activator; TACI, Total Anterior Circulation Infarcts; TCT, Trunk Control Test.

Figure 3.1 shows the ROC analysis for BI scores on days 2, 5, and 9. The AUC ranged from 0.785 for day 2 (standard error [SE]=0.035;  $p<0.001$ ; 95% CI, 0.715–0.854), 0.837 for Day 5 (SE=0.031;  $p<0.001$ ; 95% CI, 0.776–0.899), and 0.848 for day 9 (SE=0.030;  $p<0.001$ ; 95% CI, 0.788–0.908). 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 day 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 cut-off value, with the highest sensitivity and 1-specificity, was found when BI was dichotomized into  $\leq 6$  points (i.e. severe disability) and  $\geq 7$  points (i.e. moderate to mild disability).

Table 3.2 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 cut-off value of 7 points on BI in terms of predicting dichotomized BI outcome at 6 months poststroke. ORs based on a cut-off score of  $\geq 19$  points ranged from 8.013 (95% CI, 4.192–15.316) on day 2 to a maximum of 10.533 (95% CI, 5.458–20.325) on day 5. The PPV showed a gradual increase from 0.696 (95% CI, 0.645–0.739) on day 2 to 0.864 (95% CI, 0.815–0.905) on day 9, whereas the NPV declined from 0.778 (95% CI, 0.699–0.844) on day 2 to 0.613 (95% CI, 0.536–0.676) on day 9. The overall accuracy for correctly predicting outcome increased from 72.8% on day 2 to 77.2% on day 5.



**Figure 3.1** Graphic presentation of ROC analyses of timing of assessment outcome of dichotomized BI ( $\geq 19$ ) after 6 months (N=206) BI, Barthel Index.

**Table 3.2** Predictive value of dichotomized Barthel Index (BI) assessed on days 2, 5, and 9 poststroke for BI independency after 6 months (N=206)\*

Assessment	True negatives N	False negatives N	False positives N	True positives N	OR (95% CI)	Accuracy	Sensitivity (95% CI)	Specificity (95% CI)	PPV (95% CI)	NPV (95% CI)
Day 2	63	38	18	87	8.013 (4.192–15.316)	0.728	0.829 (0.768–0.879)	0.624 (0.560–0.677)	0.696 (0.645–0.739)	0.778 (0.699–0.844)
Day 5	57	23	24	102	10.533 (5.458–20.325)	0.772	0.810 (0.760–0.852)	0.713 (0.634–0.779)	0.826 (0.766–0.859)	0.704 (0.626–0.769)
Day 9	49	17	31	108	10.042 (5.082–29.842)	0.766	0.777 (0.733–0.813)	0.742 (0.650–0.819)	0.864 (0.815–0.905)	0.613 (0.536–0.676)

\*BI is 0 to 20 points.  
Using a cut-off of 7 points on BI.  
PPV, Positive Predictive Value; NPV, Negative Predictive Value.

## 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 overestimation of the final BI at 6 months. The less optimal prediction of BI at 6 months for patients assessed within 72 hours may be caused by the instability of neurological deficits as manifested by some neurological worsening during the first 24 to 48 hours after stroke observed in approximately 25% of all patients.<sup>26</sup> However, in a parallel running study focused on the timing of assessment of neurological deficits by National Institutes of Health Stroke Scale, no significant differences were found among day 2, 5, or 9.<sup>21</sup> In our opinion, a more plausible explanation could be that observers find it difficult to determine the patient's actual performance in basic ADLs when the patient is still bedridden. As a consequence, an assessment within 72 hours poststroke will underestimate the actual patients' performance. In line with the recommendation of Kasner,<sup>5</sup> our findings suggest that, even in individuals with a minor stroke who are bedridden in the first few days after stroke, the BI will underestimate outcome scores, hence making the BI 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 underpins 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<sup>27,28</sup> and because it is the most commonly used disability scale for evaluating effectiveness of stroke units.<sup>12</sup> The BI use is in line with our stroke guidelines for physical therapy<sup>18</sup> and stroke management as well as the recommendations of the Agency for Health Care Policy and Research Post-Stroke Rehabilitation Panel.<sup>28</sup> Both of these authorities recommend to use the BI<sup>28</sup> and the motor component of the Functional Independence Measure<sup>29</sup> 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,<sup>18</sup> whereas the other 2 days of assessment (i.e. days 5 and 9) were pragmatically selected based on clinical experience.<sup>16,30</sup> 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.<sup>31,32</sup> This finding suggests that the model should be reinvestigated for case mix and preferably crossvalidated in a holdout group.<sup>1,5</sup> Third, it should be emphasized that the BI is an ordinal scale. In ordinal scales, the overall score is obtained by simply adding up arbitrary numeric values assigned to a subject's ratings on a series of items. To overcome the discrete nonlinear 10 steps, we dichotomized the BI into those that achieved independency at 6 months (i.e. 19 or 20 points) and those who remained dependent in basic ADLs according to the Stroke Unit Trialist Collaboration.<sup>12</sup> However, there is little consensus about the use of these cut-offs in the literature.<sup>3</sup> Recently, it has been shown that this cut-off corresponds with 1 point on the mRS score.<sup>33</sup> Although in general, reliability of BI is considered excellent, in older individuals with cognitive impairments and when scores obtained by patient interview are compared with patient testing, reliability may not be optimal.<sup>34</sup> Furthermore, currently multiple versions of BI are in circulation, which could hamper general use and valid comparison of this measure. Moreover, although the BI is not used in all countries in the world, in most European countries, the BI is considered the gold standard for measuring ADL. In addition, missing values were imputed based on the last observation carried forward. Although relatively few (approximately 1%) missing values needed to be replaced, this may have resulted in the underestimation of the discriminative properties of the BI. Finally, the BI has been extensively tested showing good psychometric properties in terms of reliability and validity. However, this instrument is known to be insensitive to small changes in functional status, suffers from ceiling effects,<sup>3,35</sup> and allows for the use of compensation strategies when the nonparetic arm is used for grooming and eating.<sup>35-37</sup>

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