Original Article

A Clinical Predictive Score to Predict Functional Outcomes After Intensive Rehabilitation Programs for Patients with Stroke: A Retrospective Cohort Study

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ABSTRACT

Objectives: To develop a clinical predictive score to predict functional outcomes of intensive rehabilitation programs for stroke patients

Study design: A retrospective, observational cohort study

Setting: The inpatient rehabilitation ward of the Maharat Nakhon Ratchasima Hospital

Subjects: Stroke patients aged ≥ 18 years who had undergone admission for intensive rehabilitation

Methods: The study reviewed the demographic data, associated impairment, clinical assessment, and Barthel index (BI) at admission to and at discharge from the rehabilitation ward. The patient's functional outcome was classified based on the BI at discharge. Predictive variables were identified using stepwise multivariable logistic regression. A predictive score was constructed and validated.

Results: Among 250 patients, 81 achieved a good rehabilitation outcome. Eight variables were predictive of outcome: age < 70 years, interval from onset to intensive rehabilitation admission, neglect syndrome, cognitive impairment, depression, muscle strength of the affected distal upper extremity and proximal lower extremity ≥ grade 3, and Functional Ambulation Categories (FAC). These variables were used to construct a predictive score, resulting in a model with an area under the curve (AUC) of 0.77 (95%CI: 0.71, 0.83). The total score range was from 0 to 33. The Youden index determined a cutoff of 19.5, categorizing patients into two groups: good (> 19.5) and poor rehabilitation outcomes (≤ 19.5). The positive likelihood ratio for good rehabilitation outcomes was 2.32 (95%CI: 1.85, 2.90), while for poor rehabilitation outcomes, it was 0.27 (95%CI: 0.17, 0.44). Internal validity confirmed the model's good discrimination, calibration, and minimal overfitting.

Conclusions: Based on reliable and straightforward admission variables, the clinical predictive score presented in this study could help guide physicians in decision-making regarding selection of patients for admission to intensive rehabilitation programs.

Keywords: activities of daily living, rehabilitation outcome, stroke, predictive score

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Introduction

Stroke is a major global public health issue, ranking as the third leading cause of mortality and morbidity.[1] In addition to causing neurological deficits, it can also lead to various physical impairments. Rehabilitation is an effective method for improving patients' mobility and independence in daily activities.[2] It involves holistic care provided by a multidisciplinary team which includes patient assessment, diagnosis, goal setting, and collaborative care planning.[3]

Intensive rehabilitation involves a structured program in which patients are admitted to the hospital and receive at least three hours of rehabilitation therapy per day, five days a week, provided by a multidisciplinary team. Previous studies have shown that stroke patients undergoing intensive rehabilitation usually achieve better functional outcomes compared to those in non-intensive programs.[4] However, intensive programs have limitations, including high costs, limited accessibility, and prolonged hospital stays. Therefore, selection of patients for intensive programs is essential to maximize the benefits of intensive rehabilitation.

Maharat Nakhon Ratchasima Hospital is a tertiary care center providing intensive rehabilitation services. Approximately 200 patients receive services in the rehabilitation ward each year, with approximately 40 of them being stroke patients. A clinical model for predicting functional outcomes after intensive rehabilitation in stroke patients would be valuable. It would assist physicians to select appropriate candidates for the program and would help ensure efficient use of limited time and resources. Furthermore, this information could help encourage patients with strong potential for successful intensive rehabilitation to consider admission to maximize their recovery outcomes.

Several previous studies have developed clinical predictive models for stroke patients. The most commonly included predictors are age,[4-6] the interval from onset to intensive rehabilitation admission,[7] recurrent stroke,[6,8] functional ability at admission,[5,9,10] cognition,[5,11] neglect syndrome,[8] and aphasia.[8]

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However, most of these studies have focused on stroke patients in the acute phase, with only a few addressing those in the subacute or chronic phases. Under Thailand's regional healthcare system, stroke patients in all phases receive rehabilitation services. Furthermore, many of these predictive models were developed based on different patient populations and rehabilitation approaches, making them less directly applicable to our patient group. This study aimed to develop a clinical predictive score to predict functional outcomes after intensive rehabilitation programs for stroke patients. This tool is intended to help establish appropriate criteria for admitting patients to intensive rehabilitation programs.

Methods

Study design

This report is a retrospective cohort study and prognosis prediction research. On June 20, 2024, the Maharat Nakhon Ratchasima Hospital Institutional Review Board granted ethical approval (approval number 085/2024). This study has been reported according to the STROBE guideline for observational studies.

Participants

We recruited stroke patients undergoing intensive rehabilitation at the rehabilitation ward of Maharat Nakhon Ratchasima Hospital between May 2016 and April 2024. The inclusion criteria included the following requirements: age 18 years or over, a diagnosis of stroke, and consent to be admitted for intensive rehabilitation. The exclusion criteria included the following: unstable vital signs or neurological symptoms, underlying neurodegenerative diseases, e.g., Alzheimer's disease, Parkinson's disease, patients with complications that would prevent them from completing the rehabilitation program, and missing required information.

Intensive rehabilitation refers to a rehabilitation program in which patients are admitted to the hospital for rehabilitation training provided by a multidisciplinary team, including doctors, nurses, physical therapists, occupational therapists, speech therapists, and others. The training is provided for at least 3 hours a day, 5 days a week, for a minimum of 1 week.

Data collection

Data were collected from electronic hospital medical records, including patient characteristics, significant comorbidities, premorbid functional status, presence of a caregiver, history of stroke (including onset, type, and recurrence), the dates of admission and discharge from the rehabilitation ward, length of stay, impairments, and depression. Impairments, including hemiparesis, aphasia, dysphagia, neglect syndrome, and the presence of depression, were identified from medical records. Cognitive impairment was determined based on a Thai Mental State Examination (TMSE) score of ≤ 23 points. Clinical assessments conducted before and after the rehabilitation program were also reviewed. These assessments included muscle strength of the affected extremities, e.g., proximal upper extremity (shoulder abductor), distal upper extremity (wrist extensor), proximal lower extremity (hip flexor and knee extensor), and distal lower extremity (ankle dorsiflexor). Additional evaluations covered the ability to roll over in bed, transition from supine to sitting and sitting to standing, ambulation, sitting and standing balance, Functional Ambulation Categories (FAC) and the Barthel index (BI). The functional outcome was evaluated using BI.

Patients were classified into two groups: good rehabilitation outcome and poor rehabilitation outcome. A good rehabilitation outcome was defined as follows: for patients with a pre-rehabilitation BI score of 75 or less, an improvement of at least 40 points in the BI score or BI at discharge of 80 or higher[11,12] at discharge from the rehabilitation ward; and, for patients with a pre-rehabilitation BI score of more than 75, an improvement of at least 5 points in the BI score after undergoing intensive rehabilitation in the hospital. The study flow diagram is shown in Figure 1.

Sample size calculation

The sample size was calculated using G*Power software, with the Z-test family: the multiple logistic regression model[13] from Dušica's study,[11] which had a population similar to the present study. Based on a power of 80.0% with an alpha error of 0.05 and an R-Square of 0.4, the total sample size was 233 participants.

Outcome

The primary outcome was developing and validating a simplified clinical predictive score of functional outcome after an intensive rehabilitation program for patients with stroke based on essential statistical and clinical predictors.

Statistical methods

The data were analyzed using STATA version 14.0 statistical software. Potential predictors were selected based on prior knowledge from a literature review and previous predictive models. Categorical predictors are presented as frequency distributions and percentages. Continuous variables were categorized for analysis. Age was grouped as either < 70 or ≥ 70 years. The interval from onset to intensive rehabilitation admission was classified as < 3 months, 3-6 months, or > 6 months. Based on patient independence level, BI scores were divided into 0-20, 25-75, and > 75. Comparative analyses were performed using Fisher's exact test. A *p*-value of < 0.05 was considered statistically significant.

The independent predictors were identified using multiple logistic regression. Subsequently, some predictors were transferred into a multivariable model because of their clinical importance. The backward elimination of non-significant predictors was then conducted in a stepwise manner. After model reduction, the score transformation for each predictor variable was based on the multiple logistic regression coefficient of

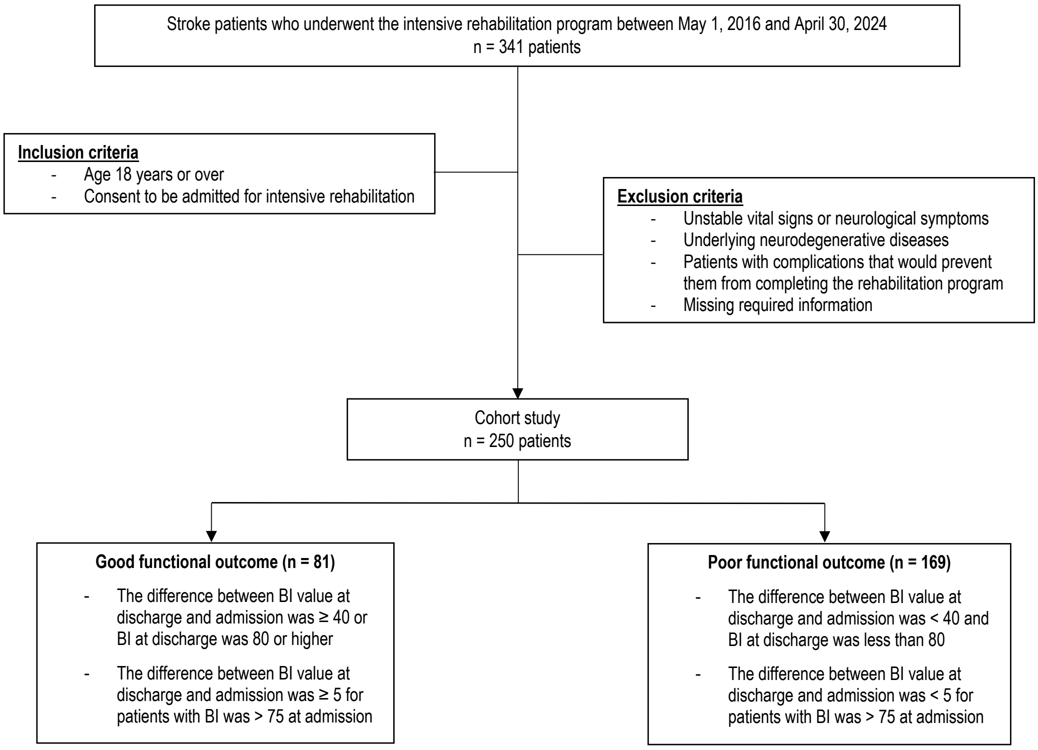

Figure 1. The study flow diagram

the variable divided by the coefficient of the variable with the smallest value. The result was then rounded to the nearest 0.5 to create a clinical predictive score for each predictor.

The score's discriminative performance was evaluated using the AuROC curve. The model's goodness-of-fit was assessed using a calibration plot. The calibration was evaluated by comparing the observed outcomes with the predicted probabilities. A polynomial of degree 2 was used to fit the calibration curve, assessing non-linear relationships between the expected and observed values. Internal validation of the clinical predictor score was performed using a bootstrapping resampling procedure with 1,000 replicates.

The total predictive scores of the patients were divided into two levels: a good rehabilitation outcome group and a poor rehabilitation outcome group. The cutoff point was determined using the Youden index. The predictive ability for rehabilitation outcomes was expressed as the likelihood ratio of a positive result and a 95% confidence interval (95%CI), with statistical significance set at a *p*-value of less than 0.05

Results

Data were collected from 250 patients, with 81 showing good rehabilitation outcomes and 169 showing poor rehabilitation outcomes. The patient's characteristics include gender, age, type of stroke, recurrent stroke, comorbidity, premorbid ambulation status, marital status, presence of a caregiver, and the interval from onset to intensive rehabilitation admission (Table 1). Statistically significant differences between the two groups in univariable analysis were found for patients over 70 years old, the presence of a caregiver, and the interval from onset to intensive rehabilitation admission.

The impairment and clinical assessment of patients were also recorded, including hemiparesis side, muscle strength (assessed using the Medical Research Council scale) on the affected side ≥ grade 3, aphasia, cognitive impairment, dysphagia, neglect syndrome, depression, sitting ability, ambulation status, BI, and FAC at admission (Table 2). The two groups showed statistically significant differences in univariable analysis for muscle strength on the affected side ≥ grade 3 in the proximal and distal parts of upper and lower extremities, cognitive impairment, neglect syndrome, sitting ability, ambulation status, BI, and FAC. FAC was categorized into three groups based on level of assistance: maximal assistance (FAC = 0), minimal to moderate assistance (FAC = 1-2), and under supervision to independent ambulation without assistance (FAC = 3-5)

Thirteen statistically significant variables in univariable analysis were included in the multiple logistic regression. Depression was added due to clinical significance. After backward stepwise selection was performed, the presence of a caregiver, muscle strength on the affected side of the proximal upper extremity and the distal lower extremity, sitting ability, ambulation status, and BI at admission were eliminated

The final predictive score was developed using two statistically significant predictors identified in our research: age < 70 years and the interval from onset to intensive rehabilitation admission, as well as six clinically significant predictors from previous studies: neglect syndrome, cognitive impairment, depression, muscle strength on the affected distal upper extremity and proximal lower extremity ≥ grade 3, and FAC. The score was calculated based on beta coefficients, resulting

Table 1. Baseline characteristics of patients with good and poor rehabilitation outcome (univariable analysis)

Variables	Good outcome (n = 81)	Poor outcome (n = 169)	*p*-value
Gender (male)[1]	61 (75.3)	117 (69.2)	0.372
Age ≥ 70[1]	4 (4.9)	28 (16.6)	0.009
Mean age (years)[2]	54.2 (11.1)	57.4 (11.4)	0.083
Ischemic stroke[1]	47 (58.0)	87 (51.5)	0.346
Recurrent stroke[1]	10 (12.4)	14 (8.3)	0.360
Comorbidity[1]			
Diabetes mellitus	25 (30.9)	43 (25.4)	0.367
Hypertension	54 (66.7)	117 (69.2)	0.771
Dyslipidemia	19 (23.5)	28 (16.5)	0.226
Atrial fibrillation	4 (4.9)	13 (7.7)	0.593
Coronary artery disease	0 (0.0)	3 (1.8)	0.553
Other	15 (18.5)	39 (23.1)	0.512
Premorbid ambulation status[1]			1.000
Independent walking without a gait aid	79 (97.5)	163 (96.5)	
Independent walking with gait aid	2 (2.5)	4 (2.4)	
Bedridden	0 (0.0)	2 (1.2)	
Marital Status[1]			0.168
Single	22 (27.2)	35 (20.7)	
Married	57 (70.4)	133 (78.7)	
Divorce	2 (2.5)	1 (0.6)	
Presence of Caregiver (yes)[1]	75 (92.6)	168 (99.4)	0.005
Interval from onset to intensive rehabilitation admission[1]			0.002
< 3 months	67 (82.7)	107 (63.3)	
3-6 months	11 (13.6)	33 (19.5)	
> 6 months	3 (3.7)	29 (17.2)	
Length of stay[2]	13.6 (10.5)	16.4 (2.3)	0.426

[1]Number (%), [2]Mean (SD)

Table 2. The impairment and clinical assessment of patients with good and poor rehabilitation outcomes (univariable analysis)

Variables	Good outcome (n = 81)	Poor outcome (n = 169)	*p*-value
Right hemiparesis[1]	43 (53.0)	77 (45.6)	0.524
Muscle power of the affected side ≥ grade 3[1]			
Proximal of UE	24 (29.6)	20 (11.8)	0.001
Distal of UE	22 (27.2)	17 (10.1)	0.001
Proximal of LE	38 (46.9)	37 (21.9)	< 0.001
Distal od LE	19 (23.4)	16 (9.5)	0.006
Aphasia[1]	20 (24.7)	54 (31.9)	0.300
Cognitive impairment[1]	13 (16.1)	56 (33.1)	0.006
Dysphagia[1]	19 (23.5)	52 (30.8)	0.294
Neglect syndrome[1]	6 (7.4)	29 (17.2)	0.050
Depression[1]	3 (3.7)	18 (10.7)	0.087
Able to change body position from supine to sit[1]	54 (66.7)	67 (39.6)	< 0.001
Ambulation status at admission[1]			0.003
Walk with/without assist	31 (38.3)	31 (18.3)	
Wheelchair ambulation	8 (9.9)	18 (10.6)	
Bedbound/bedridden	42 (51.9)	120 (71.0)	
Barthel index at admission[1]			< 0.001
0-20	19 (28.3)	48 (71.6)	
25-75	45 (27.8)	117 (72.2)	
> 75	17 (80.9)	4 (19.1)	
FAC at admission[1]			0.001
0	51 (62.9)	138 (81.7)	
1-2	18 (22.2)	25 (14.8)	
> 3	12 (14.8)	6 (3.6)	

[1]Number (%), UE, upper extremity; LE, lower extremity; FAC, Functional Ambulation Categories

Table 3. The clinical predictive score of good rehabilitation outcome, odds ratio (OR), 95% confidence interval (CI), *p*-value, beta coefficient (β), and assigned item scores

Valiables	OR	95%CI	*p*-value	Beta coefficient	Score
Age < 70 years	3.35	1.08, 10.35	0.036	1.21	4.5
No neglect syndrome	2.08	0.75, 5.73	0.159	0.73	3.0
No cognitive impairment	1.82	0.87, 3.82	0.112	0.60	2.0
No depression	2.29	0.54, 9.70	0.264	0.81	3.0
Muscle strength of distal muscle of UE ≥ 3	1.95	0.82, 4.63	0.130	0.67	2.5
Muscle strength of proximal muscle of LE ≥ 3	2.06	0.97, 4.38	0.059	0.73	3.0
Interval from onset to intensive rehabilitation admission					
< 3 months	6.83	1.89, 24.70	0.003	1.92	7.5
3-6 months	2.94	0.69, 12.54	0.144	1.08	4.0
> 6 months	1.00	Reference		0.00	0.0
FAC at admission					
0	1.00	Reference		0.00	0.0
1-2	1.29	0.57, 2.94	0.530	0.26	1.0
≥ 3	2.02	0.58, 7.03	0.270	0.70	2.5

UE, upper extremity; LE, lower extremity; FAC, Functional Ambulation Categories

in a total range of 0 to 33 (Table 3). The AUC for this total predictive score was 0.77 (95%CI: 0.71, 0.83) (Figure 2). A graphical approach to assess the goodness of fit demonstrated that the model is well-calibrated, with most points falling close to the bisector. The high *p*-value of 0.89 indicates no significant miscalibration (Figure 3). From the plot, the predicted probability of good rehabilitation outcomes increases as the score increases, showing agreement between the actual rehabilitation outcomes and the predicted risks (Figure 4).

For clinical applicability, the scores were categorized into two groups based on clinical relevance: good rehabilitation outcomes (> 19.5) and poor rehabilitation outcomes (≤ 19.5). The cutoff point was determined using the Youden index. The positive likelihood ratio for good rehabilitation outcomes was 2.32 (95%CI: 1.85, 2.90), while for poor rehabilitation outcomes, it was 0.27 (95%CI: 0.17, 0.44) (Table 4). The score showed a sensitivity of 82.7% (95%CI: 72.7, 90.2) and a specificity of 64.3% (95%CI: 56.5, 71.5). The positive predictive value was 52.8% (95%CI: 43.7, 61.7), and the negative predictive value was 88.5% (95%CI: 81.5, 93.6).

To evaluate the internal validity of the derivation model, we conducted bootstrap validation with 1,000 replications. The results reflect the model's overall predictive accuracy, discrimination, and calibration performance. The scaled Brier score was 19.4% for the apparent model performance and 18.6% after optimism adjustment via bootstrap validation. The C-statistic was 0.74 (95%CI: 0.68, 0.79) for the apparent performance and 0.74 (95%CI: 0.68, 0.80) after the optimism adjustment. This result demonstrates good discrimination, showing that the model effectively differentiates between outcomes. The E:O ratio, reflecting calibration, was 1.000

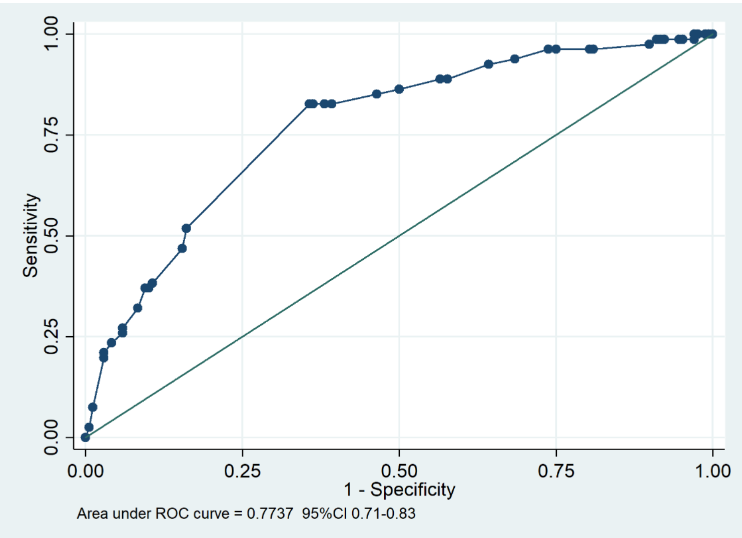

Figure 2. Area under received operating characteristic curve (AUROC) of the clinical predictive score of functional outcomes after intensive rehabilitation program for stroke patients

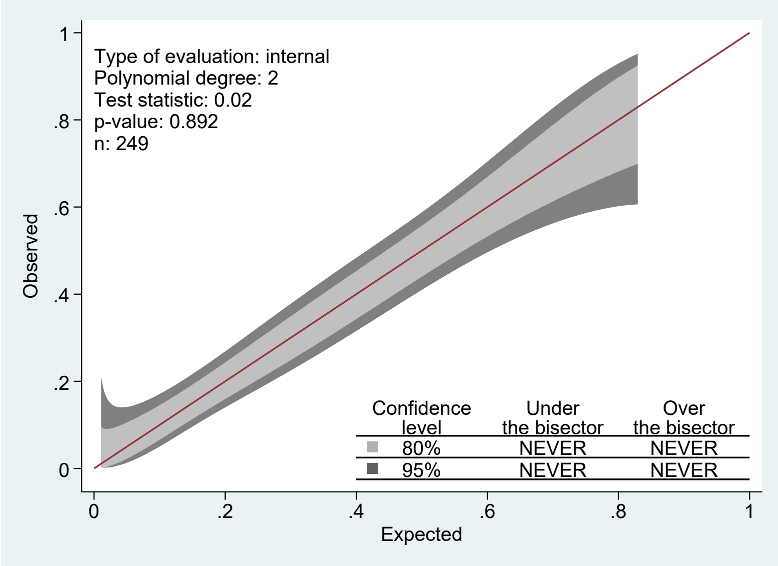

Figure 3. Calibration plot of the predicted probability of functional outcome after intensive rehabilitation program and observed functional outcome

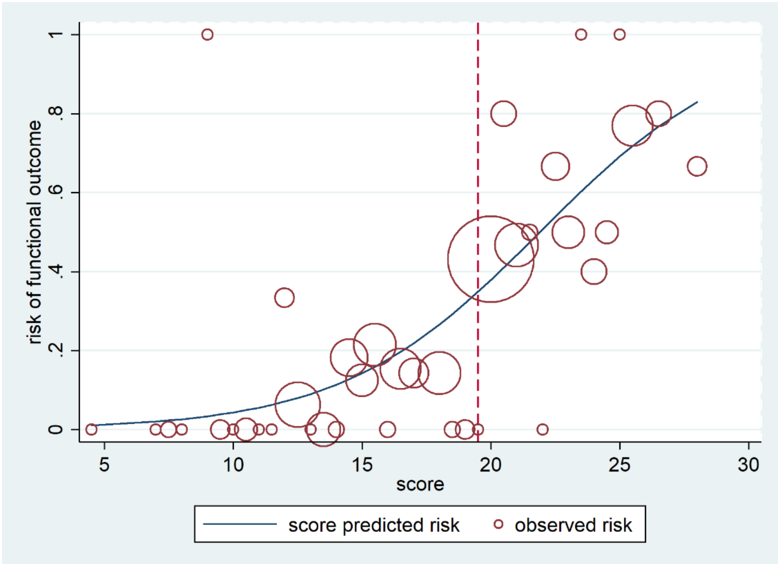

Figure 4. The risk curve analysis: observed risk of functional outcome (hollow circle) and predicted risk of the functional outcome by score (solid line), size of the circle represents the relative number of patients in each score

Table 4. Distribution of probability of functional outcome after intensive rehabilitation across the actual functional outcome

Probability categories	Score	Good functional outcome n (%)	Poor functional outcome n (%)	LR+	95%CI	*p*-value
Poor	0.0-19.5	14 (11.9)	108 (88.5)	0.27	0.17, 0.44	<0.001
Good	20.0-33.0	67 (52.8)	60 (47.2)	2.32	1.85, 2.90	<0.001

LR+, positive likelihood ratio; CI, confidence interval

for the apparent model and 1.00 (bootstrap 95%CI: 0.85, 1.16) after optimism adjustment, suggesting no significant deviation. Additionally, the heuristic shrinkage factor was 0.98 and the bootstrap shrinkage factor was 1.10, indicating minimal overfitting and further supporting the model's internal validity. These results suggest that the model demonstrates good discrimination and calibration, with minimal optimism or overfitting.

Discussion

The clinical predictive score was developed to predict the functional outcomes after intensive rehabilitation in stroke patients. The independent predictors include age < 70 years, neglect syndrome, cognitive impairment, depression, muscle strength of the affected distal upper extremity and proximal lower extremity ≥ grade 3, the interval from onset to intensive rehabilitation admission, and FAC. The total score range is from 0 to 33 points, categorizing patients into two groups based on their scores: good rehabilitation outcomes (> 19.5 points) and poor rehabilitation outcomes (≤ 19.5 points). The model demonstrated excellent discriminative performance and good calibration, indicating it is a reliable tool for predicting rehabilitation outcomes.

From the analysis using multiple logistic regressions, two predictors were statistically significant for rehabilitation outcomes: age < 70 years and the interval from onset to intensive rehabilitation admission. These findings are consistent with previous studies.[4,6,8,10-11,14-16] Age is a key factor affecting rehabilitation outcomes, as older patients often experience cognitive decline and have more comorbidities than younger patients.[17] Additionally, neuroplasticity occurs more slowly and less effectively in older patients.[18] Pohjasvaara et al. found that stroke patients over 70 years old were more dependent and disabled compared to those aged 55-70 years.[19]

In this study, the interval from onset to intensive rehabilitation admission was categorized into three groups: less than 3 months, 3-6 months, and over 6 months. This classification is based on evidence that most functional recovery occurs within the first 6 months after a stroke,[20] with the most significant recovery occurring in the first 3 months.[21] Several studies have shown that early and intensive rehabilitation improves ADL and functional outcomes more successfully than delayed rehabilitation.[22,23] Wattanapan et al. studied the effectiveness of intensive rehabilitation in stroke patients and found that shorter onset-to-admission intervals and shorter length of stay were significantly associated with better outcomes.[4]

In addition to these factors, we included clinically important variables in the model, such as neglect syndrome, cognitive impairment, depression, muscle strength on the affected side, and FAC. Neglect syndrome has been identified as a negative predictor of poor ADL outcomes.[8,15] Chen et al. studied the impact of spatial neglect in stroke rehabilitation and found that stroke patients with neglect syndrome had poorer rehabilitation outcomes, more extended hospital stays, and a higher risk of falls.[24]

Cognitive impairment is a barrier to successful rehabilitation outcomes.[5,11,15] Patients with cognitive impairment often struggle with learning, perceiving, and understanding the rehabilitation program, making it difficult for them to follow instructions effectively. Additionally, this condition reflects severe central nervous system dysfunction, which negatively impacts neuroplasticity.[25]

Depression is a common condition among stroke patients, occurring in 20.0-40.0% of cases.[26] It can lead to problems such as sleep disturbances, fatigue, altered appetite, depressed mood, loss of interest in socialization, and limited participation in rehabilitation programs. Although univariable analysis in this study did not show a statistically significant association between depression and the outcome, this may be due to the small number of patients with depression. Additionally, this was a retrospective study; some patients may not have been assessed for depression, leading to underestimation and reduced statistical power. However, based on previous research[6,11], depression is considered an important factor that may influence the outcome. Therefore, we included this variable in the predictive model.

Muscle strength is key in predicting self-care and walking ability in stroke patients. Suksatien et al. reported that muscle strength greater than grade 2 on the affected side during the acute phase of stroke was strongly associated with good long-term functional outcomes as measured by BI.[27] In this study, we included muscle strength in our predictive model, focusing on the wrist extensor, hip flexor, and knee extensor with grade ≥ 3. The wrist extensor muscle was selected due to its critical role in performing basic daily activities.[28] The hip flexor and knee extensor muscles were chosen for their importance in walking ability,[29,30] one of the BI's components.

The final predictor we selected was FAC at intensive rehabilitation program admission. Patients were categorized into three groups based on level of assistance: maximal assistance (FAC = 0), minimal to moderate assistance (FAC = 1-2), and under supervision to independent ambulation without assistance (FAC = 3-5). The FAC is a reliable indicator of motor function and trunk balance, crucial for improving independence.[16] Patients with higher FAC at admission tended to achieve better functional outcomes following intensive rehabilitation.

While previous studies have reported BI at admission predicts functional outcomes after intensive rehabilitation,[8,10,31] our findings differ. We found that BI at admission did not discriminate and predict the rehabilitation outcomes in our study. This result may be because patients with lower BI had not undergone prior rehabilitation, allowing for more significant improvements during the program. Conversely, patients with higher BI experienced minimal changes due to a ceiling effect,[32] making it less reflective of actual improvement.

Previous studies have also identified the ability to change body position from supine to sitting[9] and ambulation status at admission[15,16] as factors influencing rehabilitation outcomes after intensive rehabilitation. However, these variables were not included in the final model in our study because their inclusion did not improve its accuracy in predicting outcomes. Furthermore, ambulation status at admission closely overlapped with the FAC, making its inclusion unnecessary.

Blanco et al. developed a clinical model based on a study of 92 intensive rehabilitation patients to predict functional outcomes. A good outcome was defined as a BI score of ≥ 85 after the program. The predictors included an initial BI > 20 at admission, prior independence before the stroke, and motor deficits without sensory deficits or homonymous hemianopia. The model correctly predicted activities of daily living (ADL) outcomes in 79.0% of cases.[10] In contrast, our model incorporates cognitive and psychological factors, whereas Blanco et al.'s model primarily focuses on baseline functional status. Additionally, the applicability of Blanco et al. is limited as it included only patients capable of sitting independently and relied on a relatively small sample size.

Sodero et al. developed a clinical predictive model to estimate the modified Barthel Index (mBI) of subacute stroke patients (onset < 30 days) undergoing intensive rehabilitation. The study identified younger age, fewer comorbidities, higher cognitive abilities, lower stroke severity, and better motor function at admission as independent predictors of higher mBI at discharge. Similarly, our model included age, cognitive function, and motor function. However, comorbidities and stroke severity were not included, as comorbidities were not statistically significant in our analysis, and stroke severity had substantial missing data. A key strength of Sodero et al.'s model is its focus on the stroke subacute phase, allowing for more consistent outcomes. This difference is important, as the effects of intensive rehabilitation vary depending on the stroke phase. However, our study could not achieve this due to a limited sample size. Another strength of the Sodero study was the use of a continuous outcome measure for the model, which demonstrated exemplary reliability in its assessments (adjusted R-Squared = 77.2%).[33]

Several predictive models have been developed to estimate the Functional Independence Measure (FIM) in stroke patients following intensive rehabilitation. For example, Scrutino et al. predicted an FIM score greater than 61 (indicating mild stroke impairment) using predictors such as age, onset-to-admission interval, neglect syndrome, motor FIM and cognitive FIM. The model demonstrated high accuracy and reliability, with an area under the curve (AUC) of 0.86[6,15], and was externally validated by García-Rudolph et al. (AUC = 0.87).[34] Although their predictors are similar to ours, the assessment methods differ. Scrutino et al. used motor FIM for ambulation and cognitive FIM for cognition. In contrast, our model uses muscle strength of the affected lower extremity and FAC for ambulation and the Thai Mental State Examination (TMSE) for cognition. While FIM-based measures provide a more standardized evaluation of functional independence, our model incorporates more detailed clinical and neurological assessments. Additionally, the inclusion of depression provides a more comprehensive view of rehabilitation potential.

Another model, Harari et al., developed a model using standardized clinical tests to predict outcomes using a continuous score. Key predictors were admission scores on the FIM, Ten-Meter Walk Test (TMWT), and the Berg Balance Scale. Other factors included age, time from stroke onset to admission, education level, speech and language impairment, BMI, and hemorrhagic stroke. The model had good internal validation (adjusted R-Squared = 76.0% and MAE = 7.6).[16] Although the model included a wide range of demographic, clinical, and functional factors, relying on standardized clinical tests may make it less practical for routine rehabilitation. Moreover, the small sample size of 50 patients raises concerns about overfitting and limited generalizability.

This study had several limitations. First, as a retrospective study, some data were missing. Some predictors may not have been included in the clinical model. Some confounding factors could not be identified, potentially affecting the outcome. Second, the study was conducted in a single hospital, which may not represent the entire stroke population, limiting the generalizability of the results. However, the model demonstrated good calibration with minimal overfitting, and external validation is planned using datasets from ongoing prospective studies. Third, the sample size was insufficient for subgroup analysis or assessing rehabilitation outcomes across stroke phases (acute, subacute, and chronic), which may impact results. Lastly, the BI was used as the functional rehabilitation outcome but it is not the most precise assessment tool. Its broad score ranges may fail to capture small changes and can exhibit a ceiling effect in patients with high scores.[32] Despite these limitations, the BI remains a practical and straightforward tool, requiring minimal time to administer, and is widely used in regional and general hospitals across Thailand.

The strengths of this study are that all predictors used in the model are clinical data that can be easily collected in medical practice. Additionally, this study had an adequate sample size, and statistical analysis using a score calibration plot demonstrated that the model effectively predicts rehabilitation outcomes. This model helps predict rehabilitation outcomes even before patients are admitted for intensive rehabilitation. We do not intend this model to be used to discriminate between patients chosen to receive intensive rehabilitation and those not chosen, but rather to provide physicians with a valuable tool for guiding admission decisions, setting realistic functional goals, and planning appropriate rehabilitation programs. While some patients were categorized as having poor rehabilitation outcomes, most of them also had functional improvement after intensive rehabilitation.

Conclusion

Our study suggests that the clinical predictors for rehabilitation outcomes after intensive rehabilitation programs in patients with stroke are age < 70, the interval from onset to intensive rehabilitation, neglect syndrome, cognitive impairment, depression, muscle strength on the affected distal upper extremity and proximal lower extremity ≥ grade 3, and FAC at admission. It could help guide physiatrists and multidisciplinary teams in decision-making before admitting patients to intensive rehabilitation programs.

Conflict of interest disclosure

The authors declare no conflicts of interest.

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Data availability

The data supporting this study's findings are available on request from the corresponding author, Paveenrath Charussuriyong . The data are not publicly available because they contain information that could compromise the privacy of the research participants.

Author contribution

Paveenrath Charussuriyong : conceptualization, methodology, formal analysis, writing - review & editing,

Rachawan Suksathien: supervision.

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