Stroke

ORIGINAL CONTRIBUTION

Posterior National Institutes of Health Stroke Scale Improves Prognostic Accuracy in Posterior Circulation Stroke

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BACKGROUND AND PURPOSE: The National Institutes of Health Stroke Scale (NIHSS) underestimates clinical severity in posterior circulation stroke and patients presenting with low NIHSS may be considered ineligible for reperfusion therapies. This study aimed to develop a modified version of the NIHSS, the Posterior NIHSS (POST-NIHSS), to improve NIHSS prognostic accuracy for posterior circulation stroke patients with mild-moderate symptoms.

METHODS: Clinical data of consecutive posterior circulation stroke patients with mild-moderate symptoms (NIHSS <10), who were conservatively managed, were retrospectively analyzed from the Basilar Artery Treatment and Management registry. Clinical features were assessed within 24 hours of symptom onset; dysphagia was assessed by a speech therapist within 48 hours of symptom onset. Random forest classification algorithm and constrained optimization were used to develop the POST-NIHSS in the derivation cohort. The POST-NIHSS was then validated in a prospective cohort. Poor outcome was defined as modified Rankin Scale score ≥3 at 3 months.

RESULTS: We included 202 patients (mean [SD] age 63 [14] years, median NIHSS 3 [interquartile range, 1–5]) in the derivation cohort and 65 patients (mean [SD] age 63 [16] years, median NIHSS 2 [interquartile range, 1–4]) in the validation cohort. In the derivation cohort, age, NIHSS, abnormal cough, dysphagia and gait/truncal ataxia were ranked as the most important predictors of functional outcome. POST-NIHSS was calculated by adding 5 points for abnormal cough, 4 points for dysphagia, and 3 points for gait/truncal ataxia to the baseline NIHSS. In receiver operating characteristic analysis adjusted for age, POST-NIHSS area under receiver operating characteristic curve was 0.80 (95% CI, 0.73–0.87) versus NIHSS area under receiver operating characteristic curve, 0.73 (95% CI, 0.64–0.83), P=0.03. In the validation cohort, POST-NIHSS area under receiver operating characteristic curve was 0.82 (95% CI, 0.69–0.94) versus NIHSS area under receiver operating characteristic curve 0.73 (95% CI, 0.58–0.87), P=0.04.

CONCLUSIONS: POST-NIHSS showed higher prognostic accuracy than NIHSS and may be useful to identify posterior circulation stroke patients with NIHSS <10 at higher risk of poor outcome.

GRAPHIC ABSTRACT: A graphic abstract is available for this article.

Key Words: ataxia ■ cough ■ dysphagia ■ ischemic stroke ■ prognosis ■ reperfusion

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*A List of the Basilar Artery Treatment and Management (BATMAN) Collaboration Investigators is available in the Appendix.

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Nonstandard Abbreviations and Acronyms

AUC	area under the receiver operating characteristic
BASICS	Basilar Artery International Cooperation Study
BIC	Bayesian information criterion
mRS	modified Rankin Scale
NIHSS	National Institutes of Health Stroke Scale
OR	odds ratio
POST-NIHSS	Posterior National Institutes of Health Stroke Scale
ROC	receiver operating characteristic curves

One in 5 ischemic strokes affect the posterior circulation.[1] This subtype of stroke is associated with a high risk of recurrence, disability, and mortality.[2] The National Institutes of Health Stroke Scale (NIHSS) is a widely used scoring system to assess neurological deficits in patients with acute stroke.[3] It is an indispensable tool in treatment-decision-making and stroke research and is strongly associated with outcomes after stroke. Advantages include simplicity, rapidity of administration, and agreement between clinicians.[4–6] However, the NIHSS is strongly weighted towards deficits caused by anterior circulation lesions (such as motor function and cortical signs, especially language).[7,8] Clinical features of posterior circulation stroke such as gait/truncal ataxia, vertical gaze palsy, nystagmus, and bulbar signs are not measured, hence NIHSS scores are often lower in patients with posterior circulation stroke compared with patients with anterior circulation stroke. The NIHSS cutoff for favorable outcomes is lower in patients with posterior circulation stroke compared with patients with anterior circulation stroke, suggesting that the NIHSS underestimates clinical severity in posterior circulation stroke.[7] However, posterior circulation stroke patients presenting with low NIHSS have 23% increased odds of disability at 3 months than anterior circulation stroke patients.[8]

Previous studies have reported that >75% of patients with posterior circulation stroke present with a baseline NIHSS score of 0 to 5.[8,9] In patients presenting with mild clinical deficits, the benefit of reperfusion therapies is less certain. For instance, patients presenting with a baseline NIHSS score of 0 to 5 or having relative contraindications to intravenous thrombolysis have more finely balanced risks and benefits of thrombolysis to consider. Furthermore, whether endovascular therapy is beneficial for at least some patients with mild deficits is unclear. The recent BASICS (Basilar Artery International Cooperation Study) trial assessed the efficacy of endovascular therapy versus best medical management in patients with basilar artery occlusion and was neutral overall. However, endovascular thrombectomy benefitted patients with NIHSS score ≥10.[10] These results may lead to patients with NIHSS score <10 being less likely to receive endovascular therapy. In both these scenarios, treatment decision-making may be enhanced by an improved tool to identify patients with posterior circulation stroke presenting with lower NIHSS who nonetheless have potentially disabling symptoms and who might, therefore, benefit from thrombolysis or endovascular therapy. We assessed the prognostic value of additional clinical features in conservatively managed patients with posterior circulation stroke and mild-moderate symptoms (NIHSS score <10), and used this information to derive and validate a modified version of the NIHSS, the posterior NIHSS (POST-NIHSS). The aim of our analysis was to identify patients who were at risk of not achieving an independent outcome (modified Rankin Scale [mRS] score, 0–2) due to a clinical deficit that was more significant than indicated by the NIHSS score.

METHODS

The data that support this analysis are available from the corresponding author on reasonable request.

Patients

Clinical data of consecutive posterior circulation stroke patients with NIHSS score <10 were retrospectively analyzed from the Basilar Artery Treatment and Management registry. The Basilar Artery Treatment and Management registry is an international, multicenter registry of patients with posterior circulation stroke including recruiting sites in Australia, New Zealand, Europe, and United States.[11] Patients with a clinical and radiological diagnosis of posterior circulation stroke who were conservatively managed (not treated with intravenous thrombolysis or endovascular therapy) were included in this study. Patients treated with reperfusion therapies were excluded from this study as we were interested in investigating the natural history of posterior circulation stroke presenting with mild-moderate symptoms. The derivation cohort included patients recruited between January 2006 and May 2017. The validation cohort included patients prospectively recruited between June 2017 and December 2019. The Melbourne Health Human Research Ethics Committee approved the Basilar Artery Treatment and Management registry under a waiver of consent.

Additional Clinical Features

NIHSS and posterior circulation stroke signs were assessed by a stroke physician/neurologist in the emergency department in all patients with suspected posterior circulation stroke presenting within 24 hours of symptom onset. Posterior circulation stroke signs included were gait/truncal ataxia, diplopia, ptosis, nystagmus, internuclear ophthalmoplegia, vertical gaze palsy, Horner syndrome, palatal paralysis/hypomotility, tongue deviation, and abnormal voluntary cough. All these clinical features

were assessed as present or absent as per standard neurological examination. Gait ataxia was evaluated by instructing the patient to stand with feet together with eyes open for a few seconds and subsequently to walk naturally. If this test was normal, the patient was asked to walk in tandem, Figure 1. In patients with stroke who were unable to walk due to leg weakness, truncal ataxia was evaluated in a seated position. Dysphagia was assessed by a speech therapist within 48 hours of symptom onset.

Outcome Measures

The primary objective of our study was to assess the prognostic value of additional clinical features in posterior circulation strokes with NIHSS score <10 and derive a revised version of the NIHSS, the POST-NIHSS. Poor outcome was defined as mRS score of 3 to 6 at 3 months. Disability/death was defined as mRS score of 2 to 6 at 3 months.

Statistical Analysis

Statistical analyses were performed using IBM SPSS version 26 software (IBM SPSS Statistics, Armonk, NY) and Stata (v.15 IC, StataCorp, College Station, TX). Random forest classification and constrained optimization were conducted in Python (library: scikit-learn, version 0.23.2). Analysis of univariate data was performed using the Mann–Whitney *U* test for continuous data and Fisher exact test for categorical variables. Missing data were handled by single imputation method. Transparent reporting of a multivariable prediction model for individual prognosis or diagnosis (TRIPOD) guidelines were used (TRIPOD Checklist, Supplemental Material).

A random forest classification algorithm, which consists of multiple decision trees (100 trees, maximum depth 5) comprising multiple true or false conditions using input variables, was used to identify the most important predictors of 90-day functional outcome in the derivation cohort. Variables with larger Gini importance were considered more important.[12] Gini importance reflects how well the model fits or accuracy decreases when a variable is dropped and describes the overall explanatory power of the variables. Constrained optimization was used to identify the specific numbers of extra points to be attributed to the most important predictors of 90-day functional outcome, while maintaining the rank order from random forest classification algorithm, to maximize the area under the receiver operating characteristic (AUC) curve. These points were added to the baseline NIHSS to calculate the POST-NIHSS. Assuming that age will have an effect on outcome, logistic regression models for POST-NIHSS adjusted for age were performed to create weightings for the neurological deficits that were independent of age—thereby, the POST-NIHSS does not need to be adjusted for the individual patient's age. The model regression coefficients were then used to generate individual patients' predicted probabilities for poor outcome in the derivation and validation cohort. Receiver operating characteristic (ROC) curves for the predicted probability were subsequently calculated to assess prognostic performance in the derivation cohort and validation cohort. Nonparametric comparisons of the areas under correlated ROC curves were performed using the algorithm proposed by DeLong et al.[13] Furthermore, a bootstrapped estimate with 1000 replications was generated to provide the difference between the areas under correlated ROC curves with 95% CI. Bayesian information criterion (BIC) was used as a scalar measure to compare the overall goodness of fit for regression models incorporating different prognostic scores. Lower BIC indicates a more informative model with differences between 2 and 5 regarded as positive evidence of model superiority, differences between 5 and 10 regarded as strong evidence of model superiority, and difference >10 regarded as very strong evidence of model superiority.[14] All *P* values were 2-sided, and $P<0.05$ was considered significant.

RESULTS

Overall, 450 consecutive patients with posterior circulation stroke with complete data on NIHSS, 90-day functional outcome and additional posterior circulation stroke clinical features were analyzed from the Basilar

Gait/trunk and limb ataxia

This item is aimed at finding evidence of a unilateral cerebellar lesion. Test with eyes open. In case of visual defect, ensure testing is done in intact visual field.

- The finger-nose-finger and heel-shin tests are performed on both sides, and ataxia is scored only if present out of proportion to weakness. Ataxia is absent in the patient who cannot understand or is paralyzed. Only in the case of amputation or joint fusion, the examiner should record the score as untestable (UN) and clearly write the explanation for this choice. In case of blindness, test by having the patient touch nose from extended arm position.
- The examiner instructs the patient to stand with feet together with eyes open for a few seconds and subsequently to walk naturally. If this test is normal, ask the patient to walk in tandem. In stroke patients who are unable to walk due to limb weakness, truncal ataxia should be evaluated in sitting position by assessing trunk control.

0 Absent.
1 Present in one limb.
2 Present in two limbs.
3. Patients cannot walk or maintain a sitting position without assistance. Retro and/or lateropulsion can be present. Broad-based gait and increased sway of the body can be present.
UN Amputation or joint fusion, explain:

Figure 1. Posterior National Institutes of Health Stroke Scale (NIHSS) item 7: gait/truncal and limb ataxia.

Artery Treatment and Management registry. Of these, 378 had NIHSS score <10 and were considered for this study. Among these, 111 patients were excluded because of treatment with endovascular therapy (n=57) or intravenous thrombolysis (n=79). The excluded patients had higher NIHSS (median NIHSS score, 5 [interquartile range, 3–7] versus median NIHSS score, 3 [interquartile range, 1–5], *P*<0.001), higher rate of vertebrobasilar artery occlusion (66/111 [60%] versus 17/267 [6%]; *P*<0.001) and cardioembolic stroke etiology (49/111 [44%] versus 51/267 [19%]; *P*=0.001) compared with those not treated with reperfusion therapies and included in our analysis (Table S1). The prevalence of the clinical features analyzed to develop the POST-NIHSS was similar in patients included and excluded from the study analysis, except for dysphagia which was more present in the group of patients treated with reperfusion therapies (23/111 [21%] versus 30/267 [11%]; *P*=0.02, Table S2).

Of the 267 patients included in the analysis, 202 were in the derivation cohort and 65 in the prospective validation cohort. The flow diagram of included patients is shown in Figure S1. The 2 cohorts did not differ in their baseline characteristics, except for NIHSS which tended to be lower in the validation cohort and history of hypertension (Table 1).

Table 1. Baseline Characteristics of Conservatively Managed Posterior Circulation Stroke Patients in the Derivation Cohort and Validation Cohort

	Derivation cohort (n=202)	Validation cohort (n=65)	*P* value
Age, y, mean	63±14	63±16	0.9
NIHSS, median (IQR)	3 (1–5)	2 (1–4)	0.05
Male sex, n (%)	138 (68)	41 (63)	0.5
Risk factors, n (%)			
Hypertension	128 (63)	28 (43)	0.01
Hypercholesterolemia	67 (33)	17 (26)	0.2
Diabetes	58 (29)	12 (18)	0.08
Atrial fibrillation	29 (14)	9 (14)	0.9
Smoking	56 (28)	25 (38)	0.2
Coronary artery disease	23 (11)	10 (15)	0.5
Previous stroke or TIA	37 (18)	7 (11)	0.1
Stroke etiology,* n(%)			
Cardioembolic	39 (19)	12 (18)	0.9
Atherosclerotic	38 (19)	11 (17)	
Small vessel disease	28 (14)	11 (17)	
Other	13 (6)	10 (15)	
Undetermined	74 (37)	21 (32)	
Vertebrobasilar artery occlusion, n (%)	11 (5)	6 (9)	0.4

IQR indicates interquartile range; NIHSS, National Institutes of Health Stroke Scale; TIA, transient ischemic attack; and TOAST, Trial of ORG 10172 in Acute Stroke Treatment.
*TOAST classification.

Derivation of the POST-NIHSS

In the derivation cohort, we included 202 posterior circulation stroke patients, mean age 63 (SD, 14); median NIHSS score, 3 (interquartile range, 1–5). Among these, 31/202 (15%) patients had poor outcome and 70/202 (35%) had disability/death at 3 months. In univariate analysis, older age, higher NIHSS, female sex, coronary artery disease, and previous stroke/TIA were significantly associated with poor outcome at 3 months (Table 2). Data on gait ataxia were available in 178/202 patients. Gait/truncal ataxia (*P*=0.02), abnormal (absent or weak) voluntary cough (*P*=0.01) and dysphagia (*P*=0.004) were the additional clinical features strongly associated with poor outcome (Table 3). Abnormal cough was associated with dysphagia in 100% (n=7/7) of cases, Table 2. In logistic regression analysis adjusted for age, gait/truncal ataxia (odds ratio [OR], 3.14 [95% CI, 1.24–7.92], *P*=0.02), dysphagia (OR, 5.22 [95% CI, 1.63–16.7], *P*=0.005), and abnormal voluntary cough (OR, 8.17 [95% CI, 1.49–44.8], *P*=0.02) were significantly associated with poor outcome. Gait ataxia outperformed limb ataxia in logistic regression analysis for poor outcome adjusted for age (gait ataxia OR, 3.14 [95% CI, 1.24–7.92], *P*=0.02 BIC 127 versus limb ataxia OR, 2.36 [95% CI, 1.04–5.38], *P*=0.04 BIC 159). Age, NIHSS, abnormal voluntary cough, dysphagia, and gait/truncal ataxia were ranked as the 5 most important predictors of 90-day functional outcome in the random forest classification algorithm (Figure 2). After constrained optimization, 5 points for abnormal cough, 4 points for dysphagia, and 3 points for gait/truncal ataxia were identified as the optimal weighting of additional points to maximize the POST-NIHSS ROC curve. The POST-NIHSS was therefore calculated by adding 3 points for gait/truncal ataxia, 4 points for dysphagia, and 5 points for abnormal cough to the baseline NIHSS. In logistic regression analysis for poor outcome adjusted for age, the POST-NIHSS performed well against the NIHSS (POST-NIHSS OR, 1.21 [95% CI, 1.09–1.34], *P*=0.001 BIC 150 versus NIHSS OR, 1.20 [95% CI, 1.02–1.42], *P*=0.03 BIC 158). In ROC analysis for poor outcome adjusted for age, the POST-NIHSS outperformed NIHSS (POST-NIHSS AUC was 0.80 [95% CI, 0.73–0.87] versus NIHSS AUC, 0.73 [95% CI, 0.64–0.83], bootstrapped difference in AUC, 0.06 [95% CI, 0.002–0.12], DeLong *P*=0.03, bootstrapped *P*=0.049).

In the derivation cohort, 156/202 (77%) patients presented with NIHSS 0 to 5. In a sensitivity analysis in this subgroup of patients, POST-NIHSS remained significantly associated with poor outcome in logistic regression analysis adjusted for age (OR, 1.40 [95% CI, 1.14–1.70], *P*=0.01), whereas NIHSS did not (OR, 1.12 [95% CI, 0.82–1.56], *P*=0.46). In logistic regression

Table 2. Outcomes in the Derivation Cohort

	Good outcome (n=171)	Poor outcome (n=31)	*P* value
Age, y, mean	62±14	72±13	0.001
NIHSS,* median (IQR)	3 (1–5)	5 (3–6)	0.001
Female sex, n (%)	49 (29)	15 (48)	0.04
Risk factors, n (%)			
Hypertension	106 (62)	22 (71)	0.4
Hypercholesterolemia	53 (31)	14 (45)	0.2
Diabetes	48 (28)	10 (32)	0.7
Atrial fibrillation	21 (12)	8 (26)	0.09
Smoking	59 (35)	9 (29)	0.6
Coronary artery disease	15 (9)	8 (26)	0.01
Previous stroke or TIA	26 (15)	11 (35)	0.01
Stroke cause,* n (%)			
Cardioembolic	46 (27)	10 (32)	0.5
Atherosclerotic	43 (25)	10 (32)	
Small vessel disease	24 (14)	8 (26)	
Other	15 (9)	1 (3)	
Undetermined	72 (42)	10 (32)	
Basilar artery occlusion, n (%)	9 (5)	2 (6)	0.7

IQR indicates interquartile range; NIHSS, National Institutes of Health Stroke Scale; TIA, transient ischemic attack; and TOAST, Trial of ORG 10172 in Acute Stroke Treatment.

*TOAST classification.

Table 3. Clinical Features Associated With Poor Outcome in the Derivation Cohort

	All patients (n=202)	Good outcome (n=171)	Poor outcome (n=31)	*P* value
Gait/truncal ataxia,* n (%)	68 (38)	54 (35)	14 (61)	0.02
Diplopia, n (%)	31 (15)	27 (16)	4 (13)	0.8
Ptosis, n (%)	10 (5)	6 (4)	4 (13)	0.05
Nystagmus, n (%)	44 (22)	35 (21)	9 (29)	0.3
Internuclear ophthalmoplegia, n (%)	7 (4)	5 (3)	2 (7)	0.3
Vertical gaze palsy, n (%)	7 (4)	4 (2)	3 (10)	0.8
Horner's syndrome, n (%)	3 (2)	2 (1)	1 (3)	0.4
Palatal paralysis/hypomotility	16 (8)	12 (7)	4 (13)	0.3
Tongue deviation, n (%)	10 (5)	7 (4)	3 (10)	0.2
Dysphagia, n (%)	16 (8)	9 (5)	7 (23)	0.004
Abnormal cough,† n (%)	7 (4)	3 (2)	4 (13)	0.01

*Data on gait ataxia were available in 178 patients.

†Abnormal cough was associated with dysphagia in 7/7 (100%) of cases.

analysis for slight disability/death adjusted for age, the POST-NIHSS model performed favorably compared with the NIHSS model (POST-NIHSS OR, 1.29 [95% CI, 1.11–1.50], *P*=0.001 BIC 180 versus NIHSS OR, 1.44 [95% CI, 1.15–1.80], *P*=0.002 BIC 183, the difference of 3 in BIC indicating positive evidence in favor of the POST-NIHSS model).

Validation of the POST-NIHSS

In the validation cohort, 65 posterior circulation stroke patients (mean age, 63 [SD, 16]; median NIHSS score, 2 [interquartile range, 1–4]) were prospectively recruited. Among these, 17/65 (26%) had poor outcome and 26/65 (40%) had disability at 3 months. Results of univariate analysis in the validation cohort are shown in Table S3. Abnormal cough was associated with dysphagia in 100% (n=5/5) of cases. In logistic regression analysis for poor outcome adjusted for age, POST-NIHSS outperformed NIHSS (POST-NIHSS, 1.43 [95% CI, 1.16–1.77], *P*=0.001 BIC 56 versus NIHSS OR, 1.34 [95% CI, 1.05–1.70], *P*=0.02 BIC 68). In ROC analysis adjusted for age, POST-NIHSS showed significantly higher accuracy than NIHSS (POST-NIHSS AUC, 0.82 [95% CI, 0.69–0.94] versus NIHSS AUC, 0.73 [95% CI, 0.58–0.87]; bootstrapped difference in AUC, 0.09 [95% CI, 0.004–0.175], DeLong *P*=0.04, bootstrapped *P*=0.04).

In the validation cohort, 57/65 (88%) patients presented with NIHSS score, 0–5. In a sensitivity analysis in this subgroup of patients, POST-NIHSS remained significantly associated with poor outcome in logistic regression analysis adjusted for age (OR, 1.41 [95% CI, 1.11–1.78], *P*=0.005), whereas NIHSS did not (OR, 1.33 [95% CI, 0.88–2.03], *P*=0.18). Similarly, POST-NIHSS remained significantly associated with disability/death in logistic regression analysis adjusted for age (OR, 1.29 [95% CI, 1.06–1.57], *P*=0.01), whereas NIHSS did not (OR, 1.23 [95% CI, 0.85–1.78], *P*=0.28).

In the pooled derivation and validation cohort, POST-NIHSS identified 17% (n=36/213) of patients with NIHSS score, 0 to 5 (hence, potentially less likely to be considered for intravenous thrombolysis) who had additional potentially disabling symptoms. Among these patients, 14/36 (39%) had poor outcome (mRS score, 3–6) and 24/36 (67%) had slight disability/death (mRS score, 2–6) at 3 months. Similarly, among patients with vertebrobasilar artery occlusion and NIHSS score, 0 to 9 (and hence potentially less likely to be considered for endovascular therapy), POST-NIHSS identified 18% (n=3/17) patients with additional potentially disabling symptoms. All 3 patients had poor outcome (mRS score, 3–6) at 3 months.

We then assessed the performance of POST-NIHSS in patients treated with reperfusion therapies and excluded from the main study analysis. In logistic regression analysis for poor outcome adjusted for age, the POST-NIHSS model performed favorably compared with the NIHSS model (POST-NIHSS OR, 1.24 [95% CI, 1.08–1.41], *P*=0.002 BIC 101 versus NIHSS OR, 1.31 [95% CI, 1.07–1.61], *P*=0.009 BIC 106, the difference of 5 in BIC indicating positive evidence in favor of the POST-NIHSS model).

We, therefore, propose the POST-NIHSS: a modified version of the NIHSS including testing of gait/truncal

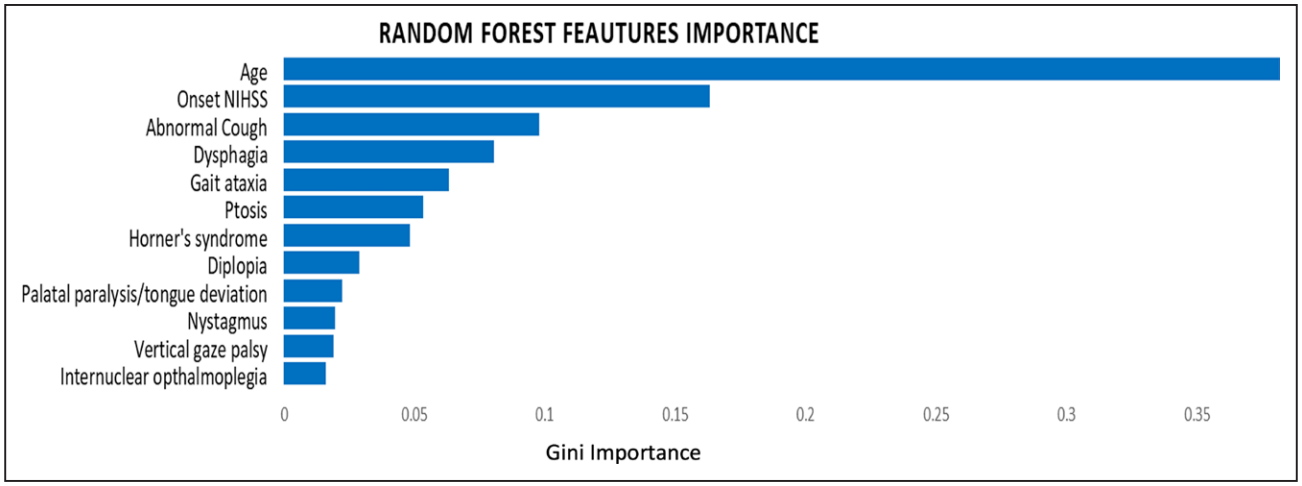

Figure 2. Random Forest features importance.
Gini importance describes the overall explanatory power of the variables. NIHSS indicates National Institutes of Health Stroke Scale.

ataxia, voluntary cough, and swallowing, where 3 points are given for gait/truncal ataxia in item 7 (gait/truncal and limb ataxia, Figure 1). If there is both limb ataxia as well as gait/truncal ataxia, 3 points should be given. An algorithm to assess bulbar signs is then performed in an additional item 12 (Figure 3). The algorithm to assess bulbar signs is based on the preliminary investigation/indirect swallowing test and the Swallow Liquid attempt of the Gugging Swallowing Screen[15] which has been well-validated and used by clinicians from multidisciplinary backgrounds.[16]

DISCUSSION

We developed the POST-NIHSS, a modified version of the NIHSS including assessment of gait/truncal ataxia and bulbar signs, which appears to improve NIHSS prognostic accuracy in patients with posterior circulation stroke presenting with mild-moderate symptoms. The incorporation of gait ataxia and bulbar signs assessment in a structured tool may help with early prognostication for posterior circulation stroke patients presenting with mild symptoms by identifying those at higher risk of poor outcome. Although patients with NIHSS score <10 were included in our study, the median NIHSS in our derivation and validation cohort was 3 and 2, respectively, a group in whom thrombolysis or endovascular therapy may not routinely be used. Therefore, POST-NIHSS may assist clinicians in treatment-decision making in selected patients (eg, patients presenting with NIHSS score 0–5 or having relative contraindications to reperfusion therapies in whom the risks and benefits of treatment should be carefully weighed). Moreover, a structured examination approach may standardize and simplify neurological assessments in the hyperacute phase. The additional items can be readily performed at the bedside. Truncal ataxia can be tested when gait ataxia is not testable, voluntary cough, and dysphagia should be assessed with the patient upright. We anticipate that an algorithm to assess bulbar signs would be more practical and less time-consuming in a time-critical setting such as acute stroke. Cough is examined first and if normal the examiner proceeds to a preliminary oral examination to exclude obvious anatomic abnormalities (palatal paralysis/asymmetry or tongue deviation) which would suggest the presence of bulbar signs and likely dysphagia. Water swallow test is only performed if preceding steps are normal. In patients with stroke, impaired cough and dysphagia are often present in parallel, given the shared neural and anatomic substrates of cough and swallowing function, and assessment of cough may provide a noninvasive way to identify patients at risk of aspiration.[17] Conversely, assessing dysphagia when voluntary cough is not preserved could put the patient at risk of aspiration in the acute setting and consequent aspiration pneumonia. We propose an algorithm in which cough is examined first and if absent or weak, this suggests the presence of bulbar signs and likely dysphagia (cough is scored 9 points=5 for abnormal cough+4 for dysphagia). Indeed, abnormal cough was associated with dysphagia in 100% of cases in our cohort. Therefore, we believe this justifies adding 9 points for abnormal cough.

Dysphagia occurs in up to two-thirds of patients with stroke and can lead to serious complications such as aspiration pneumonia and malnutrition.[18] It has been associated with prolonged hospital stays, higher admission rates to residential care facilities and increased mortality.[19] Poor cough is a particularly strong predictor of aspiration pneumonia[20] and was strongly associated with poor outcome in our data. Impaired gait and trunk control are common in patients with stroke, even if limb ataxia is not present. In our study, more than a third of posterior circulation stroke patients presented with gait/truncal ataxia, consistent with previous studies.[21] Gait ataxia increases the risk of falls and impairs independence of

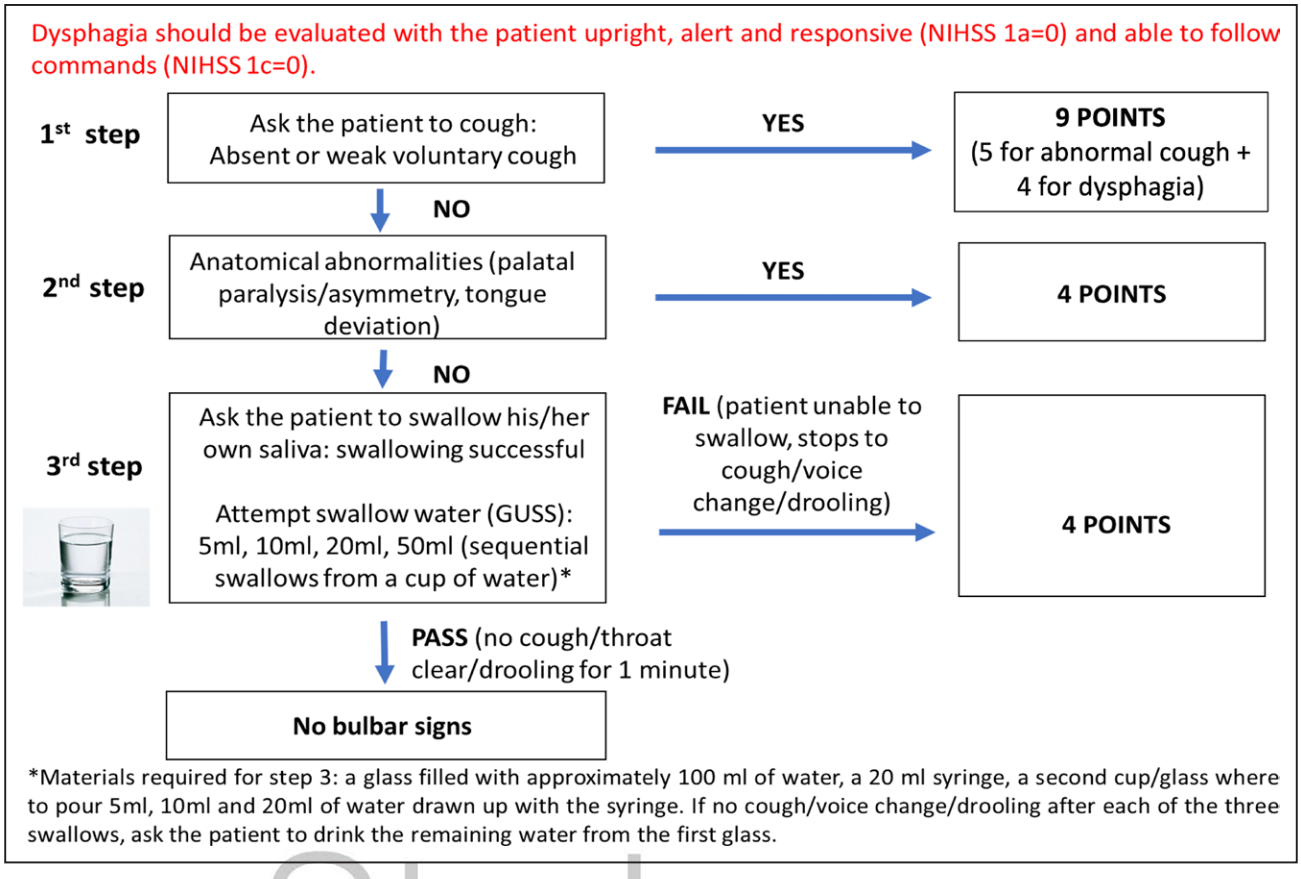

Figure 3. Posterior National Institutes of Health Stroke Scale (NIHSS) item 12: bulbar signs.
GUSS indicates Gugging Swallowing Screen.

activities of daily living. Balance status is associated with longer hospitalization periods and poststroke disability.[22]

Current stroke guidelines recommend that intravenous thrombolysis may be reasonable for patients with mild disabling stroke symptoms within 4.5 hours of symptom onset.[23] Our data provide greater clarity on what constitutes potentially disabling symptoms in posterior circulation strokes and, therefore, may support increased utilization of intravenous thrombolysis in this patient group. Furthermore, the potential risk of hemorrhagic transformation appears to be lower in posterior circulation stroke in comparison with anterior circulation stroke.[24,25] The same approach could be adopted for patients presenting with low NIHSS but otherwise eligible for endovascular therapy. Therefore, the POST-NIHSS may be useful in all patients in whom physicians are unsure about treatment with intravenous thrombolysis or endovascular therapy because of lower NIHSS scores. In our study, up to 26% of patients with NIHSS score <10 had poor outcome and up to 40% had disability at 3 months. These findings are consistent with previous studies.[8,9] To date, there is no validated alternative scale to the NIHSS for posterior circulation stroke patients. The Israeli Vertebrobasilar Stroke Scale is a 44-point scoring system which was developed in a cohort of 43 patients with vertebrobasilar stroke, containing 11 items (including dysphagia and gait ataxia) and using an arbitrary weighting system based on clinical experience.[26] Dysphagia was tested by instructing patients to swallow 3 consecutive teaspoons of water followed by half a glass of water and recording any swallowing difficulties (coughing or wet voice) which appeared feasible. In this study, inter-rater agreement between 2 examiners was excellent for both dysphagia and gait ataxia. More recently, Olivato et al[27] developed an extended version of the NIHSS (the expanded NIHSS) in 22 patients with posterior circulation stroke and 25 with anterior circulation stroke, to improve the NIHSS diagnostic accuracy in posterior circulation stroke. This scale included additional items such as trunk ataxia, nystagmus, Horner syndrome, IX and XII cranial nerve deficits, which were weighted using an arbitrary scoring system. Both the expanded NIHSS and the Israeli Vertebrobasilar Stroke Scale score were developed in small cohorts, used arbitrary scoring systems, and did not demonstrate a higher prognostic accuracy in comparison with the NIHSS. We developed a simple, pragmatic, and rapid tool that may assist clinicians in treatment-decision making. POST-NIHSS is easy to perform as it includes clinical features that should be assessed after NIHSS whenever a posterior circulation stroke is suspected. A de novo scoring system alternative to the NIHSS, would add more complexity to

the neurological assessment, given diagnosing posterior circulation stroke can be challenging and clinicians may be unsure on which scale to use. Although model performance usually tends to worsen in validation data sets, the POST-NIHSS prognostic accuracy improved, likely due to the lower NIHSS (median NIHSS score, 2) in the validation cohort compared with the derivation cohort.

Our study has several limitations. Dysphagia assessment was performed by a speech therapist within 48 hours and not by the physician, concurrently with the NIHSS. Moreover, it was not assessed using the same screening tool in all patients. We have suggested a practical and well-validated approach for the rapid bedside assessment of dysphagia to allow this to be performed concurrently with the NIHSS. Although the score was derived using machine learning algorithms, which have been proven to have high accuracy in predicting stroke outcomes[28] and was prospectively validated, the POST-NIHSS requires further validation in larger prospective data sets. Similarly, the association between POST-NIHSS and slight disability/death in patients presenting with mild symptoms (NIHSS score, 0–5) needs further testing in larger cohorts. Patients treated with reperfusion therapies were excluded from the main study analysis as we were interested in investigating the natural history of posterior circulation stroke presenting with mild-moderate symptoms. However, the POST-NIHSS performed favorably compared with the NIHSS in n=111 patients treated with reperfusion therapies, and we would not expect a lower prevalence of the POST-NIHSS signs to negatively affect the performance of the score in patients treated with reperfusion therapies. Nonetheless, this needs further validation in larger cohorts including the whole population of posterior circulation strokes. The score inter-rater reliability must be evaluated. However, similar gait and dysphagia assessments showed excellent reliability in previous studies.[16,26] Furthermore, the Gugging Swallowing Screen had a sensitivity of 100%, a specificity of 69% in predicting dysphagia (confirmed by fiberoptic endoscopic evaluation), and a robust inter-rater reliability (k=0.835)[16] when conducted by stroke nurses within 24 hours of onset. Although we do not anticipate inter-rater agreement to be significantly worse when performed by stroke physicians, this requires further validation.

Use of the POST-NIHSS does not require a-priori differentiation between anterior and posterior circulation stroke. Standard NIHSS should be performed in all patients with stroke and the POST-NIHSS (assessment of gait ataxia and bulbar signs) could be added at the end of the NIHSS in patients presenting with low scores, to ascertain the presence of disabling symptoms that may require treatment, or for prognostication. Given dysphagia and gait/truncal ataxia can be present in patients with anterior circulation strokes (frontal lobe, basal ganglia, corona radiata lesions), this approach could potentially be applied regardless of the stroke topography, subject to validation of the POST-NIHSS in patients with anterior circulation stroke and low NIHSS.

CONCLUSIONS

The POST-NIHSS has higher prognostic accuracy than NIHSS in patients with posterior circulation stroke presenting with mild-moderate symptoms (NIHSS score <10). POST-NIHSS, which includes assessment of gait/truncal ataxia and bulbar signs, may be useful to identify posterior circulation stroke patients presenting with low NIHSS who may be at higher risk of poor outcome and might benefit from reperfusion therapies.

ARTICLE INFORMATION

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Supplemental Materials

Figure S1
Tables S1–S3
TRIPOD Checklist

APPENDIX

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