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Validation of Stroke Network of Wisconsin Scale at Aurora Health Care System

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Abstract

Background—The Stroke Network of Wisconsin (SNOW) scale, previously called the Pomona scale, was developed to predict large-vessel occlusions (LVOs) in patients with acute ischemic stroke (AIS). The original study showed a high accuracy of this scale. We sought to externally validate the SNOW scale in an independent cohort.

Methods—We retrospectively reviewed and calculated the SNOW scale, the Vision Aphasia and Neglect Scale (VAN), the Cincinnati Prehospital Stroke Severity (CPSS), the Los Angeles Motor Scale (LAMS), and the Prehospital Acute Stroke Severity Scale (PASS) for all patients who were presented within 24 hours after onset at AHCS (14 hospitals) between January 2015 and December 2016. The predictive performance of all scales and several National Institute of Health Stroke Scale cutoffs (≥6) were determined and compared. LVO was defined by total occlusions involving the intracranial internal carotid artery, middle cerebral artery (MCA; M1), or basilar arteries.

Results—Among 2183 AIS patients, 1381 had vascular imaging and were included in the analysis. LVO was detected in 169 (12%). A positive SNOW scale had comparable accuracy to predict LVO and showed a sensitivity of 0.80, specificity of 0.76, the positive predictive value (PPV) of 0.31, and negative predictive value of 0.96 for the detection of LVO versus CPSS ≥ 2 of 0.64, 0.87, 0.41, and 0.95. A positive SNOW scale had higher accuracy than VAN, LAMS, and PASS.

Conclusion—In our large stroke network cohort, the SNOW scale has promising sensitivity, specificity and accuracy to predict LVO. Future prospective studies in both prehospital and emergency room settings are warranted.

Keywords

Acute stroke; stroke scales; prehospital emergency care; vessel occlusion

Introduction

The benefit of mechanical thrombectomy within six hours for anterior circulation acute ischemic stroke (AIS) due to large-vessel occlusion (LVO) is clear. However, the clinical outcome is highly associated with the time to recanalization [1], with each 30-min delay in time to reperfusion, reducing the risk of a good outcome by 12%–15% [2]. Prolonged onset to puncture and image to puncture times is significantly associated with a decreased chance of good outcome [3].

Considering the limited availability of comprehensive stroke centers (CSCs) and time sensitivity of intravenous tissue plasminogen activator and mechanical thrombectomy, it is of utmost importance to recognize and triage early LVO patients in both prehospital and in-hospital settings.

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There are several LVO screening scales currently in use, including the Los Angeles Motor Scale (LAMS), the Rapid Arterial occlusion Evaluation (RACE) scale, the Cincinnati Prehospital Stroke Scale (CPSS), the vision, aphasia, and neglect (VAN), the Prehospital Acute Stroke Severity (PASS), the Field Assessment Stroke Triage for Emergency Destination (FAST-ED), the Three-Item Stroke Scale, and several shortened variations of the National Institutes of Health Stroke Scale (NIHSS) [4–10]. While all of these screening scales have been used to specifically screen for LVO, they have limitations. The LAMS, RACE, CPSS and NIHSS scales have been studied prospectively in a prehospital setting [11,12,20]. The LAMS does not include highly discriminating cortical findings and scoring of the scale elements is subjective. The RACE scoring system is cumbersome for emergency medical technicians and nurses as it requires six items to score, thereby making it more complex and time-consuming. The CPSS scale does not incorporate cortical signs and its sensitivity to detect LVO is low at 56% in one independent cohort [6,9]. The VAN scale is comprised of 10 different items and it also requires visual field test, limiting its utility to emergency medical system (EMS) personnel.

Given these limitations of established LVO screening scales, we recently proposed an alternative for LVO screening: the Stroke Network of Wisconsin scale (SNOW scale, previously known as Pomona scale). The SNOW scale is a very simple scale derived from the NIHSS. It incorporates cortical signs and it includes three items: Speaking difficulty/expressive aphasia (S), Neglect (N), and Ocular deviation (O). A SNOW scale is positive if any one of the findings is present.

The scale was first tested retrospectively in an acute stroke activation cohort from Pomona Valley Hospital and showed high sensitivity (98%), specificity (50%), and accuracy (74%) for the detection of LVO [13]. We now further validate the SNOW scale to confirm that it is translatable to another AIS cohort.

Subjects and Methods

The Aurora St. Luke's Medical Center Institutional Review Board approved this retrospective chart review. The medical records for all patients diagnosed with AIS between January 2015 and December 2016 at Aurora Health Care System Hospital were reviewed. AIS patients without vascular imaging were excluded from the final analysis.

Using the admission neurological exam, scores for the SNOW, VAN, CPSS, LAM, PASS, and NIHSS variants scales were retrospectively calculated. The scores were then correlated with the presence of LVO as determined by vascular imaging [MRA, computed tomography angiogram (CTA), and catheter angiogram] to determine the predictive performance of each scale. LVO was defined as unilateral acute complete symptomatic occlusion of the intracranial internal carotid artery (intracranial ICA), M1 segment of the MCA or basilar artery (BA). The primary outcome of interest was how accurately each scale would have predicted LVO.

Statistical Method

The clinical characteristics of LVO and non-LVO (NLVO) patients were compared using descriptive statistics. Multivariate regression analysis was used to determine the predictive significance of the components of the SNOW scale. The sensitivity, specificity, and PPV and negative predictive value (NPV), likelihood ratios and performance using receiver operating characteristic (ROC) curve analysis [area under the curve (AUC)] were calculated. A two-sided p-value of < 0.05 was considered significant. All the statistical analysis was performed using SAS 9.4 version, SAS Institute, Gary, NC, USA.

Results

Among 2183 AIS patients presenting within 24 hours, 1381 (63%) had vascular imaging and were included in the analysis. Among the patients with vascular imaging, LVO was confirmed in 169 (12%). The characteristics of LVO and NLVO patients in the vascular imaged cohort are compiled in Table 1. The LVO patients were older (71.13 ± 14.6 vs. 68.8 ± 14.2, $p = 0.034$), were more often female (53% vs. 45%, $p = 0.057$), and had higher severe NIHSS (17.21 ± 9.5 vs. 5.5 ± 16.7, $p < 0.0001$) score than NLVO patients. The site of occlusion was: MCA-M1, 88 patients (52%); distal ICA, 52 (31%); and BA, 29 (17%).

A positive SNOW scale had comparable accuracy to predict LVO as the CPSS ≥ 2, and NIHSS ≥ 6. A positive SNOW scale had higher accuracy (area under the ROCs curve) than VAN, LAMS, and PASS: positive SNOW scale = 0.78 as a reference; VAN = 0.67, $P < 0.001$; LAMS ≥ 4 = 0.62, $P < 0.001$, and PASS ≥ 2 = 0.69, $P < 0.001$. A positive SNOW scale had sensitivity of 0.80, specificity of 0.76, PPV of 0.31, and NPV of 0.96 for the detection of LVO versus CPSS ≥ 2 of 0.65, 0.87, 0.41, and 0.95, respectively (Table 2, Figure 1).

Table 1. Baseline patient characteristics with and without large vessel occlusion

Characteristic	Total (N = 1381)	LVO (N = 169)	NLVO (N = 1212)	P-value
Age (years), mean (SD)	69.1 ± 14.3	71.3 ± 14.6	68.8 ± 14.2	0.0342
MaleFemale	736 (53.3%)645 (46.7%)	78 (46.2%)91 (53.8%)	658 (54.3%)554 (45.7%)	0.0470
NIHSS (mean, SD)	6.96 ± 8.0	17.2± 9.5	5.5 ± 6.7	<0.0001
Hypertension	1139 (82.5%)	144 (85.2%)	995 (82.1%)	0.3191
Atrial fibrillation	366 (26.5%)	74 (43.8%)	292 (24.1%)	<0.0001
Prior stroke	1093 (79.2%)	132 (78.1%)	961(79.3%)	0.7227
Diabetes	462 (33.5%)	48 (28.4%)	414 (34.2%)	0.1374
Smoking	813 (58.8%)	89 (52.7%)	724 (59.7%)	0.0800

LVO, large-vessel occlusion; NLVO, non-LVO

Table 2. Stroke scale parameters comparing SNOW scale to other scales

	Stroke scale parameters with 95% confidence interval						
Stroke scale	Sensitivity	Specificity	PPV	NPV	AUC[†]	SE	P-value
SNOW	0.80 (0.75–0.86)	0.76 (0.74–0.78)	0.31 (0.27–0.36)	0.97 (0.95–0.98)	0.78 (0.75–0.81)	0.02	Reference
VAN	0.45 (0.38–0.53)	0.88 (0.86–0.90)	0.34 (0.28–0.41)	0.92 (0.91–0.94)	0.67 (0.63–0.71)	0.02	<0.0001
LAM ≥ 4	0.31 (0.24–0.39)	0.93 (0.91–0.94)	0.37 (0.29–0.45)	0.91 (0.89–0.92)	0.62 (0.58–0.66)	0.01	<0.0001
CPSS ≥ 2	0.65 (0.58–0.72)	0.87 (0.85–0.89)	0.41 (0.35–0.47)	0.95 (0.93–0.96)	0.76 (0.72–0.80)	0.02	0.2100
PASS ≥ 2	0.51 (0.43–0.58)	0.87 (0.86–0.89)	0.36 (0.30–0.42)	0.93 (0.91–0.94)	0.69 (0.65–0.73)	0.02	<0.0001
NIHSS ≥ 6	0.85 (0.79–0.90)	0.67 (0.64–0.70)	0.26 (0.23–0.30)	0.97 (0.96–0.98)	0.76 (0.73–0.79)	0.02	0.1400

PPV, positive predictive value; NPV, negative predictive value; AUC, area under the curve; SE, standard error

Table 3. Percent of cases for chance of LVO, missing LVO and chance of false LVO

Scale	Score	Chance of LVO	Chance of missing LVO	Chance of false LVO
SNOW	Positive	80%	20%	24%
VAN	Positive	46%	54%	12%
CPSS	≥2	65%	35%	13%
LAM	≥4	31%	69%	7%
PASS	≥2	51%	49%	13%
NIHSS	≥6	85%	15%	33%

LVO, large-vessel occlusion; NLVO, non-LVO; SNOW, Stroke Network of Wisconsin

The ROC curves of positive SNOW scale, LAMS, RACE, CPSSS, and PASS when applied on the entire test cohort are shown in Figure 2.

In both univariate and multivariate analyses, all SNOW positive items were significantly associated with LVO (Table 3). The strongest predictor of LVO among the SNOW items was gaze deviation with a sensitivity = 0.54 (95% CI, 0.47–0.62), specificity = 0.91 (0.90–0.93), AUC = 0.73, and odds ratio = 4.6 (2.9–7.3).

Discussion

In this independent cohort of AIS patients, we found that a positive SNOW scale has the highest sensitivity, accuracy, and excellent discriminatory ability in predicting LVO. A positive SNOW had 80% sensitivity and 76% specificity. A patient with a SNOW score of one, two, or three had an LVO 17%, 41%, and 98% of the time, respectively. Similar to our original study [13], the current data confirm that the gaze deviation is the best predictor for LVO. Weakness is specifically not included as a test element in that it is not an exclusively cortical sign and, when included in the scoring, actually decreased sensitivity considerably, from 81% to 44% (data not shown).

Why is this important? The largest study of AIS patients undergoing thrombectomy with a stent retriever demonstrated that every hour of delay from EMS scene arrival to puncture time was associated with a 5.5% absolute decline in achieving a good functional outcome [14]. A delay in transferring the patient also reduced the likelihood of performing AIS intervention by 2.5% for each minute of transfer time [15]. The interval between onset and ED arrival was strongly associated with the degree of collateral circulation preserved, the extent of infarcts, and clinical outcome after revascularization [16].

Considering the time-sensitive nature of the clinical outcome, there needs to be fast and accurate triage of patients to hospitals that can provide the necessary level of care. For example, the STRATIS study showed that patients who were transferred from a primary stroke center (PSC) to an endovascular capable CSC experienced a median delay in time to reperfusion of 109 min, translating to an approximately 8% lower chance of independent survival [14]. Similarly, the HERMES study found that the time to reperfusion was two hours longer in patients requiring a transfer from PSC to CSC [17].

In an effort to avoid the delays associated with initial transport to a PSC, prehospital clinical identification of

AIS patients with LVO is an emerging field of study as evidenced by the several screening scales developed to predict LVO. However, with accuracies ranging between 0.75 and 0.80, and high false positive and false negative rate, these scales are imperfect [18,19]. Nevertheless, a screening tool is still needed to ensure that the LVO patients are expediently transported or transferred to an appropriate facility. The optimal LVO screening scale is one that is simple, accurate, reliable, valid, and proven to improve patient outcome [16]. Moreover, the screening tool should be applicable in the field so that paramedics can use it for prearrival notification and patient triage and in the emergency rooms without acute vascular imaging availability [15,16].

Of the screening scales developed to predict LVO in the prehospital setting, most have not been externally validated to determine the presence of LVO. LAMS and RACE scales are the only two scales that have been validated in the prehospital settings [11,12]. Both scales were easy to learn but showed low specificities (58–68%) when performed by paramedics. RACE is more complex with six signs to identify, including motor symptoms, making it less specific for LVO [5]. Moreover, LVO was diagnosed using a transcranial doppler in the RACE study which is less accurate than CTA. LAMS scale is very subjective as it tests for facial weakness and hand grip with no cortical signs testing [4]. CPSS is a simple scale with high sensitivity (0.84) from the original study, however, external validation of the scale showed sensitivity of 0.70 which is relatively low to consider for screening [6, 21]. VAN scale is derived from data from only 62 acute stroke activations, though it showed very high NPV the result could be overestimated. VAN also requires visual field testing, which is challenging to perform in the prehospital setting [7]. PASS scale is derived from very selective cohort of AIS patients who received IV-tPA or endovascular therapy [8]. The scale items look similar to CPSS, except CPSS requires testing for following commands [6]. The sensitivity of PASS is even lower than CPSS (0.66) but it has higher specificity (0.83). FAST-ED scale has similar accuracy to CPSS and RACE scale, but it suffers from very low sensitivity (0.60) [9].

These limitations of LVO screening tools demanded the development and validation of a much simpler and more accurate scale like SNOW scale. We also believe that due to the simplicity of SNOW scale, this can be taught to other health care professionals that indirectly work with stroke patients and community individuals, thereby increasing the awareness of LVO as a whole.

Our study has several limitations. First, the NIHSS scores were calculated from the initial examinations of trained nurses and not by the emergency medical responders, therefore, the accuracy of the scale's application might vary. Second, this study only included known AIS patients; applying SNOW to a prospective EMS derived stroke alert dataset will be important. Third, we did not compare the SNOW scale with all existing prehospital scales which includes RACE, FAST-ED, and 3I stroke scales because of their complexity, low sensitivity, and the inadequate validation of the scales, respectively. Fourth, one-third of our AIS patients did not have vascular imaging and, therefore, were excluded from the analysis; this may affect the performance of the scale. Fifth, in comatose or intubated patients, expressive aphasia and neglect are not assessable. In these critically illpatients, direct transport to a CSC with neurointensive care facilities, if geographically feasible, seems reasonable. Sixth, expressive aphasia is very subjective and it could lead to more false positive results of the scale. Finally, stroke is an evolving condition and as time goes by the exam can change so that the scoring that was obtained at the scene could be different from the scoring at the time of the ED exam. These differences were not noted in the current study.

In conclusion, the SNOW scale is a simple objective score based on three elements of the routine neurological examination: neglect, expressive aphasia, and gaze deviation. A positive SNOW scale will correctly identify 80% of patients with LVO as having LVO, this is superior to the other scales and highly comparable to NIHSS ≥ 6. A positive SNOW scale will also incorrectly identify 24% of NLVO patients as having an LVO. While not the lowest false positive rate, in the field, we would rather err on over diagnosing rather than under diagnosing LVO (Table 4). This suggests that a patient with a positive SNOW score should be promptly treated at a center with vascular imaging and neurointerventional capabilities. Future prospective studies in both prehospital and emergency room settings are needed to evaluate the real-time effectiveness of the scale in AIS.

Acknowledgements

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Table 4. Univariate and multivariate factors in predicting association between individual SNOW scale items and LVO in logistic regression analyses

	Univariate				Multivariate			
Predictor of LVO	**OR**	**95% CI**		***P*-Value**	**OR**	**95% CI**		***P*-Value**
Gaze deviation	12.60	8.76	18.11	<0.0001	4.58	2.86	7.33	<0.0001
Expressive Aphasia	5.19	3.70	7.30	<0.0001	3.03	2.04	4.50	<0.0001
Neglect	12.26	8.58	17.51	<0.0001	3.88	2.43	6.19	<0.0001

LVO, large-vessel occlusion

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