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Original Article

Comparison of prehospital stroke assessment scales for acute ischemic stroke with large vessel occlusion within six hours of onset: A single-center study in Eastern Taiwan

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Abstract

Objectives: In Taiwan, acute ischemic stroke (AIS) with large vessel occlusion (LVO) remains a significant health concern. Reperfusion therapy is more effective if the patient arrives at the medical center within the early time window, emphasizing the importance of prehospital stroke assessment to identify LVO and rapid transfer. This study focused on Eastern Taiwan, where the Hualien Tzu Chi Hospital is the sole comprehensive stroke center. We compared different prehospital stroke assessment scales in identifying LVO. **Materials and Methods:** We reviewed 598 patients with acute stroke admitted to our hospital's emergency department between April 1, 2021, and March 31, 2022. Of these, 110 AIS cases presenting within 6 h of symptom onset were retrospectively analyzed using the medical records and National Institute of Health Stroke Scale (NIHSS) scores to evaluate the efficacies of prehospital stroke scales, including our institution's Tzu Chi Stroke Severity Scale and its modified version. LVO was defined as occlusion of the anterior cerebral artery, middle cerebral artery, and its main branches, intracranial carotid arteries, and vertebrobasilar arteries. **Results:** Among 110 patients, 39.1% had LVO, which showed a higher mortality rate and prevalence of atrial fibrillation. LVO had higher NIHSS scores and longer hospital stays. The Vision Aphasia Neglect (VAN) Scale and Modified Tzu Chi Stroke Severity Scale showed the highest sensitivity, with the latter also exhibiting the highest sensitivity for posterior circulation LVO. **Conclusion:** The VAN and the modified Tzu Chi Stroke Severity Scale offer comparable sensitivity for detecting LVO in the prehospital setting. Our study supports the adoption of the modified Tzu Chi scale in the regional emergency medical service transfer algorithm for LVO detection for timely intervention.

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Introduction

Although age-standardized stroke rates have decreased globally, the annual number of stroke cases and stroke-related deaths has increased significantly among those aged 70 years and above. Stroke remained the second-leading cause of death worldwide and the third-leading cause of death and disability combined [1]. In Taiwan, stroke-related morbidity and mortality continue to exert a considerable burden as the fourth leading cause of death [2].

Acute ischemic stroke (AIS) due to large vessel occlusion (LVO) accounts for 38.7% of all cases of AIS, which contributes to 61.6% of poststroke dependence or death and 95.6% of poststroke mortality. AIS due to LVO has a substantially higher rate of dependence or death within a span of 3–6 months compared to non-LVO counterparts [3]. Early reperfusion therapy, including endovascular thrombectomy (EVT), has substantially enhanced survival rate and functional outcome [4,5]. An early time window of 6 hours from the onset of symptoms has emerged as the preferable period for initiating EVT since the benefits of

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reperfusion wane if the interval between symptom onset and thrombectomy initiation increases [6]. Door-to-needle time and EVT procedural times have significantly shortened over the past decade. However, the prehospital component of "onset-to-door" time remains stagnant [7], indicating an area for potential optimization. Therefore, prehospital stroke assessment tools have been developed to identify potential LVO cases for prompt prioritization and transfer to facilities with neuro-interventional capabilities. Nonetheless, it is essential to consider the regional context when implementing these tools.

In Eastern Taiwan, encompassing the Hualien-Taitung region, the Hualien Tzu Chi Hospital stands as the sole tertiary center offering comprehensive stroke care, including EVT and a neurointensive care unit. We use an emergency medical service (EMS) transfer algorithm with Tzu Chi Stroke Severity Scale for emergency medical technician (EMT) personnel. This algorithm aims to assess the likelihood of LVO in acute stroke patients, facilitating swift transfer to a comprehensive tertiary center. However, the validation and comparison of the scale with other established prehospital scales have yet to be undertaken. Therefore, this study undertook a comparative analysis of various prehospital stroke assessment scales, including our Tzu Chi Stroke Severity Scale and its modified version, based on the data obtained from acute stroke patients registered within the same hospital during a specific period and examined the basic demographics of the study population.

Materials and methods

Ethics

This study was approved by the research ethics committee of our hospital (IRB113-121-B) and conducted in accordance with the Declaration of Helsinki. Informed written consent was waived because the study was a retrospective data analysis.

Study population

We conducted a retrospective review of medical records and National Institute of Health Stroke Scale (NIHSS) scores for patients with AIS who were admitted to the emergency department (ED) between April 1, 2021, and March 31, 2022. Neurologists performed and recorded the NIHSS at the time of admission at the ED.

During this period, 598 patients with acute stroke were admitted. Among these, 143 patients (23.92%) were diagnosed with hemorrhagic stroke, whereas 455 patients (76.09% of the total) were ischemic stroke. Among the ischemic stroke patients, only 111 (24.3%) arrived at the hospital within 6 hours of symptom onset, but one patient was excluded from the study due to incomplete medical records. The remaining 110 patients were analyzed for demographic data and comparison of prehospital stroke scales.

The study included an assessment of associated risk factors such as hypertension, diabetes mellitus, heart disease, hyperlipidemia, and a history of previous stroke for all patients.

Definition of large vessel occlusion

The study defines LVO as occlusion of both the anterior circulation (internal carotid artery, anterior cerebral artery, and middle cerebral artery including M1 and M2 branches) and posterior circulation (basilar artery and vertebral artery). This definition aligns with the Taiwan National Health Insurance guidelines for endovascular therapy eligibility. Confirmation of LVO is conducted through radiological evaluation using magnetic resonance angiography or computerized tomographic angiography.

Comparison of the prehospital stroke assessment scales

Prehospital stroke assessment scales were retrospectively evaluated based on the medical records and NIHSS recorded during ED admission. They included Cincinnati Stroke Triage Assessment Tool (C-STAT), Field Assessment Stroke Triage for Emergency Destination (FAST-ED), Los Angeles Motor Scale (LAMS), Prehospital Acute Stroke Severity Scale (PASS), Rapid Arterial oCclusion Evaluation scale (RACE), 3-item stroke scale, 3-step ambulance clinical triage for acute stroke treatment (ACT-FAST) algorithm, Vision Aphasia Neglect (VAN) scale, Tzu Chi stroke severity scales, and its modified version for comparison and analysis of their sensitivities. Each established prehospital stroke scale evaluates different scoring systems as prescribed in Table 1. C-STAT, FAST-ED, LAMS, PASS, RACE, and 3-item use scores (continuous variables), whereas others use positive/negative (categorical variables).

Our Tzu Chi stroke severity scale is the part of the EMS transfer algorithm for acute stroke used in the Hualien-Taitung region. It encompasses two steps: first, the patient is assessed by an EMT personnel using the Cincinnati Prehospital Stroke Scale, in which the EMT checks whether the patient has facial droop, arm drift, or speech disturbance. If any of these are present, the patient is presumed to have a stroke. Then, the Tzu Chi stroke severity scale is used to check for LVO likelihood. This scale includes an assessment of the altered level of consciousness, conjugate eye deviation, and no antigravity in muscle strength of the upper and/or lower limbs. If a patient with acute stroke symptoms presents with 2 out of 3 items, they are transferred directly to a comprehensive medical center for reperfusion therapy. If the transfer distance is substantial, the patient may be first transported to a local hospital en route, which offers emergency stabilization and thrombolysis therapy. Then, suitable patients with neuroimaging evidence of LVO will be transferred to the medical center [Figure 1]. EMT staff are trained to assess the Cincinnati scale, muscle strength, and assessment of the level of consciousness.

To increase the scale's sensitivity, a modified version of the Tzu Chi Stroke Severity Scale is proposed, wherein the test is regarded as positive if any of the three items is present.

Statistical analysis

The data were expressed as frequencies, proportions, and medians (the interquartile range) depending on the characteristics of each item. When comparing the baseline demographics between two groups (non-LVO vs. LVO), statistical tests were performed. Wilcoxon rank-sum test was used to compare the medians of continuous variables. The Chi-squared test or Fisher's exact test was used to evaluate the association between two the categorical variables. A receiver operating characteristic (ROC) curve was used to evaluate the performance of various prehospital stroke assessment

Table 1: The established prehospital scales and their items to be checked

Prehospital stroke assessment scales	**C-STAT [8]**	**FAST-ED [9]**		**LAMS [10]**	**PASS [11]**
Items to be checked (and their scores)	Conjugate gaze deviation (2) Arm falls within 10 s (1) Incorrect response to questions or failure to follow at least one command (1)	Facial palsy Normal or minor (0) Partial or complete (1) Arm weakness Drift or some effort against gravity (1) No effort against gravity or no movement (2) Speech change Mild to moderate (1) Sever, global aphasia, mute (2) Eye deviation Partial (1) Forced (2) Neglect Extinction to bilateral simultaneous stimulation (1) Not recognize own hand or orient only to on side of the body (2)		Facial droop (1) Arm drift Drift down (1) Rapid fall (2) Grip strength Weak grip (1) No grip (2)	Incorrectly answering for month and/or age (1) Gaze palsy/deviation (1) Arm weakness (1)
Interpretation	LVO: ≥2	LVO: ≥4		LVO: ≥4	LVO: ≥2
Prehospital stroke assessment scales	**RACE [12]**	**3-Items [13]**	**ACT-FAST [14]**	**VAN [15]**	**Tzu Chi and modified Tzu Chi**
Items to be checked (and their scores)	Facial palsy Mild (1) Moderate to severe (2) Arm motor impairment Moderate (1) Severe (2) Leg motor impairment Moderate (1) Severe (2) Head/gaze deviation (1) Agnosia (left-sided weakness) Mild (1) Severe (2) Aphasia (right-sided weakness) Mild (1) Severe comprehensive deficit (2)	Conscious disturbance Mild (1) Severe (2) Head/gaze deviation Partial (1) Forced (2) Hemiparesis Moderate (1) Severe (2)	First step Unilateral arm drift <10 s Second step Language deficit Severe deficit (right arm weak) Gaze deviation/ hemineglect (left arm weak)	First step Arm drift or weakness Second step Vision defect (V) Aphasia (A) Neglect (N)	First step Facial droop Arm drift Speech disturbance Second steps Altered consciousness Conjugate eye deviation No antigravity in muscle strength of the upper and/or lower limbs
Interpretation	LVO: ≥5	LVO: ≥4	LVO: Any sign of the second step	LVO: Any of VAN with arm drift of weakness	LVO Tzu Chi: Any of the signs of the first step and two signs of the second step Modified Tzu Chi: Any sign of the first and second steps

LAMS: Los Angeles Motor Scale, C-STAT: Cincinnati stroke triage assessment tool, FAST-ED: Field assessment stroke triage for emergency destination, PASS: Prehospital Acute Stroke Severity Scale, LVO: Large vessel occlusion, RACE: Rapid Arterial oCclusion Evaluation scale, VAN: Vision aphasia neglect, ACT-FAST: 3-step ambulance clinical triage for acute stroke treatment, Tzu Chi: Tzu Chi Stroke Severity Scale

scales, and the area under the curve (AUC) was calculated to determine the discrimination ability of the ROC curve.

Finally, the sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and accuracy indices were used to compare the predictive effects of various prehospital stroke assessment scales in diagnosing LVO among patients admitted to the ED within 6 h of stroke onset. Statistically significant differences were defined as $P < 0.05$.

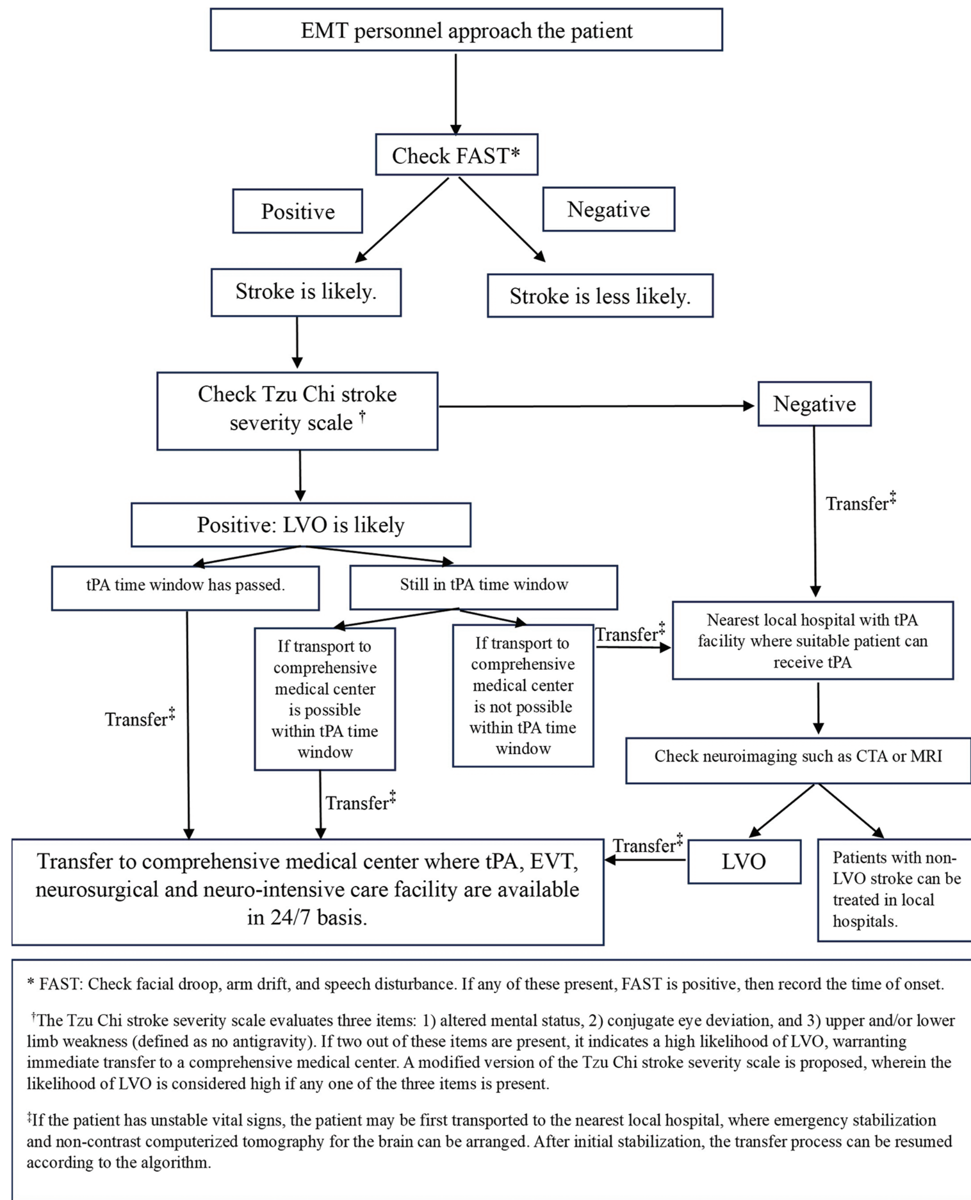

Figure 1: The figure shows the flow chart of the emergency medical service transfer algorithm with the Tzu Chi Stroke Severity Scale. It illustrates the transfer algorithm for patients with stroke utilized in Eastern Taiwan incorporating the Tzu Chi stroke severity scale. In addition, a modified version of the Tzu Chi stroke severity scale is proposed for enhanced sensitivity in detecting large vessel occlusion. EMT: Emergency medical technician, EVT: Endovascular thrombectomy, tPA: tissue plasminogen activator, LVO: Large vessel occlusion

All analyses were conducted using the SPSS software version 21.0 (IBM Corp., Armonk, NY, USA).

Using AI tools

We employ artificial intelligence (AI) tools such as ChatGPT and Grammarly for editing purposes, focusing on grammar, spelling, and sentence structure.

Results

Study population and demographic characteristics

Among the 110 patients included in the study, 43 (39.1%) were identified to have LVO, 33 of which were anterior circulation strokes, and 10 of which were posterior circulation strokes. LVO cases were linked to higher NIHSS scores (14 in LVO vs. 3 in non-LVO) and longer hospital stays (10 days in LVO vs. 6 days in non-LVO). Nine mortality cases (8.2%) occurred during hospital stays, all of which were LVO cases (20.9% mortality rate for LVO cases vs. 0% mortality for non-LVO cases). The overall male-to-female ratio in the study population was 2.06. This ratio was less distinct in LVO cases (1.69). The median age of patients with acute stroke with LVO was 73 years, whereas that of non-LVO patients was 67 years [Table 2]. Hyperlipidemia is significantly more prevalent in non-LVO groups, and cardiac diseases were significantly associated with LVO cases (55.8% of all LVO cases). Furthermore, atrial fibrillation (AF) was subsequently isolated for comparative analysis; 83.3% of LVO patients with heart disease had AF, resulting in 46.5% of LVO cases having AF. Only 22.4% of non-LVO cases had AF. Nearly two-thirds of the patients had hypertension, and

Table 2: Demographic, morbidity, and mortality of the study population (*n*=110)

Item	Acute ischemic stroke within 6 h of onset			*P*
	Non-LVO	LVO	Total	
n	67	43†	110	
Age	67 (17)	73 (20)	70 (18.5)	0.122
Length of stay (day)	6 (6)	10 (20)	6 (10.25)	0.002
NIHSS	3 (4)	14 (16)	5 (12)	<0.001
Sex				
Male	47 (70.1)	27 (62.8)	74 (67.3)	0.422
Female	20 (29.9)	16 (37.2)	36 (32.7)	
Comorbidity				
Hypertention	48 (71.6)	33 (76.7)	81 (73.6)	0.553
DM	28 (41.8)	21 (48.8)	49 (44.5)	0.468
Previous stroke	17 (25.4)	10 (23.3)	27 (24.5)	0.801
Hyperlipidemia	33 (49.3)	12 (27.9)	45 (40.9)	0.026
Heart disease‡	22 (32.8)	24 (55.8)	46 (41.8)	0.017
Atrial fibrillation§	15 (22.4)	20 (46.5)	35 (31.8)	0.008
Death during hospitalisation	0	9 (20.9)	9 (8.2)	<0.001

†43 patients had large vessel occlusions, of which 33 were anterior circulation strokes and 10 were posterior circulation strokes, ‡Heart diseases encompasses valvular heart disease, coronary artery disease, heart failure, atrial fibrillation, and other structural heart abnormalities. The correlation with atrial fibrillation was subsequently isolated for comparative analysis between LVO and non-LVO stroke cases, §83.3% of LVO patients with heart disease had atrial fibrillation, resulting in 46.51% of LVO cases having atrial fibrillation. Data are presented as *n* (%) or medians (IQR). IQR: Interquartile range, LVO: Large vessel occlusion, NIHSS: National Institutes of Health Stroke Scale, DM: Diabetes mellitus

half of the patients had diabetic mellitus. Almost one-fourth of patients in both groups had a history of previous stroke. However, there were no significant differences in incidences of hypertension, diabetic mellitus, and previous stroke among LVO and non-LVO cases [Table 2].

Comparison of the prehospital stroke assessment scales

Comparison of the prehospital stroke assessment scales utilizing numerical scoring systems (C-STAT, FAST-ED, LAMS, PASS, RACE, and 3-items) revealed significantly higher median scores in the LVO groups [Table 3]. Within each scale, instances of false-positive cases were observed; particularly, the modified Tzu Chi, VAN, and PASS scales exhibited relatively high false positives [Table 4], impacting their PPV [Table 5]. The median score of 3-item scale was lower in our study cohort compared to its established cutoff values [Table 3]. A comparison of the sensitivity, specificity, PPV, NPV, and accuracy of various prehospital stroke scales was presented in Table 4. The sensitivity of prehospital scales ranged from 34.88% in the 3-item stroke scale to 76.74% in VAN. Our Tzu Chi stroke severity scale exhibited modest sensitivity (58.14%). The modified version of the Tzu Chi stroke severity scale had improved overall sensitivity (74.42%), comparable to that of the VAN scale. The modified Tzu Chi scale also showed the highest sensitivity for posterior circulatory LVO stroke, whereas all other scales demonstrated limited sensitivity in detecting posterior circulation LVO, with sensitivity as low as 20% in the 3-item scale.

Table 3: A comparison of the median (interquartile range) scores of prehospital stroke assessment scales that utilize numerical score systems

Prehospital stroke assessment scales	Non-LVO (*n*=67), *n* (%)	LVO (*n*=43†), *n* (%)	Total, *n* (%)	*P*
C-STAT	1 (1)	3 (3)	1 (3)	<0.001
FAST-ED	1 (2)	5 (3)	2 (3.25)	<0.001
LAMS	1 (2)	4 (2)	2 (4)	<0.001
PASS	1 (1)	2 (2)	1 (2)	<0.001
RACE	1 (3)	5 (4)	2 (5)	<0.001
3-Items	0 (1)	3 (3)	1 (3)	<0.001

†43 patients had large vessel occlusions, of which 33 were anterior circulation strokes and 10 were posterior circulation strokes. C-STAT: Cincinnati stroke triage assessment tool, FAST-ED: Field assessment stroke triage for emergency destination, LAMS: Los Angeles Motor Scale, LVO: Large vessel occlusion, PASS: Prehospital Acute Stroke Severity Scale, RACE: Rapid Arterial oCclusion Evaluation scale, 3-items: 3-items stroke scale

The ROC analysis for the six assessment scales, which use scoring systems, suggested that the new cutoffs should be applied for our population's FAST-ED, RACE, and 3 items [Table 6] to improve sensitivity significantly. If anterior and posterior circulation strokes are considered separately, four optimal cutoffs can be changed to increase sensitivity to detect the anterior-circulation LVO, whereas three optimal cutoffs need to be changed to screen posterior-circulation LVO [Table 6]. Overall, diagnostic accuracies of FAST-ED and RACE with optimal cutoffs are slightly better than that of the modified Tzu Chi scale, especially in anterior circulation strokes. We assessed the discriminatory power of VAN, which showed the highest sensitivity with the original cutoff value in our study, the original Tzu Chi stroke severity scale, and its modified version by comparing their respective area under the curve (AUC) based on ROC curves [Figure 2]. All three scales exhibited favorable discriminatory ability for screening LVO, with AUC values of 0.787, 0.753, and 0.753, respectively. Their discriminatory power was more pronounced in anterior circulation strokes [Figure 2]. No statistically significant difference was observed in the AUC values among the three scales [Appendix 1]. Table 7 shows the number and distribution of the components of the Tzu Chi Stroke Severity Scale related to the number and distribution of intracranial LVO in our study. Altered mental status was found to be insensitive for the M2 branch of the middle cerebral artery.

Discussion

In recent years, acute stroke care in Taiwan has shown significant strides, marked by improvements in thrombolytic therapy rates and door-to-needle time [16], resulting in a decline in early case-fatality rates [17]. Despite these advancements, the prehospital component of "onset-to-door" time remains a pressing challenge, especially for LVO, as median intervals between symptom onset and ED arrival range from 71 to 335 min [18,19]. Similar challenges are observed in neighboring regions such as China, where a recent study reported only 11.79% of patients arrived at hospitals within 3 h [20]. There is a clear need to prioritize prehospital triage

strategies capable of effectively screening for LVO and rapid transfer to appropriate levels of care [21].

In Eastern Taiwan, approximately, 70% of acute stroke cases are referred to our center, particularly those requiring intensive stroke care [22]. Nevertheless, timely transfers remain a challenge in this region, where only 24.3% of AIS arrived within 6 h. Our study focused on patients who arrived at the ED within 6 h of symptom onset. This timeframe aligns with the preferable early window for reperfusion therapy, where EVT within 6 h of onset has significant clinical benefits [6].

Table 4: The number (and percentage) of radiologically confirmed large vessel occlusion and nonlarge vessel occlusion cases, while the prehospital stroke assessment scales suggested large vessel occlusion

Prehospital stroke assessment scales	Non-LVO (*n*=67)	LVO (*n*=43†)	Total	*P*
C-STAT (cut-off score≥2)	9 (13.4)	25 (58.1)	34 (30.9)	<0.001
FAST-ED (cut-off score≥4)	11 (16.4)	29 (67.4)	40 (36.4)	<0.001
LAMS (cut-off score≥4)	8 (11.9)	29 (67.4)	37 (33.6)	<0.001
PASS (cut-off score≥2)	13 (19.4)	29 (67.4)	42 (38.2)	<0.001
RACE (cut-off score≥5)	9 (13.4)	27 (62.8)	36 (32.7)	<0.001
3-Items (cut-off score≥4)	3 (4.5)	15 (34.9)	18 (16.4)	<0.001
ACT-FAST	7 (10.4)	29 (67.4)	36 (32.7)	<0.001
VAN	13 (19.4)	33 (76.7)	46 (41.8)	<0.001
Tzu Chi	5 (7.5)	25 (58.1)	30 (27.3)	<0.001
Tzu Chi (modified, lower cut-off)	16 (23.9)	32 (74.4)	48 (43.6)	<0.001

ACT-FAST: The 3-step ambulance clinical triage for acute stroke treatment algorithm, C-STAT: Cincinnati stroke triage assessment tool, FAST-ED: Field assessment stroke triage for emergency destination, LAMS: Los Angeles Motor Scale, LVO: Large vessel occlusion, PASS: Prehospital Acute Stroke Severity Scale, RACE: Rapid Arterial oCclusion Evaluation scale, Tzu Chi: Tzu Chi Stroke Severity Scale, VAN: Vision Aphasia Neglect, 3-items: 3-items stroke scale

Our study also revealed some insight into the acute stroke epidemiology of Eastern Taiwan. In Taiwan, ischemic stroke constitutes 77% of the first-ever strokes, with a male-to-female ratio of 1.48 for IS [17]. Our study observed a similar proportion of ischemic strokes (76.09% of total patients) with a similar prevalence of LVO-AIS (39.1%) [3], although with a more pronounced male-to-female ratio (2.06). For Eastern Taiwan, LVO-AIS primarily affected elderly people with comorbidities (median age of 73 years). The longer hospital stay, higher NIHSS score, and high mortality (20.9%) of LVO underscore its burden.

Approximately half of LVO strokes in our study had AF, consistent with those reported in Western studies [23], highlighting the need for comprehensive cardiac evaluation in LVO-AIS. While hypertension and diabetes were equally prevalent in both LVO and non-LVO groups, hyperlipidemia was significantly more prevalent in non-LVO cases, underscoring the crucial role of lipid management in small vessel disease.

The regional context influences the sensitivity and feasibility of the prehospital scales, as observed in different regional settings [21]. NIHSS is the most widely used score for assessing stroke severity during hospital admission. However, its complexity limits its utility as prehospital screening [21]. Its efficacy in screening for LVO varies across different studies, with cutoff scores ranging from 6 to 10, and the predictive value diminishes over time from symptom onset [21,24]. The performance of RACE and VAN scales also vary substantially across regions. The RACE scale showed 85% sensitivity in a prospective trial in Germany [12], but it only had a modest sensitivity of 67% in an observational study in the Netherlands [25]. The sensitivity of the VAN

Table 5: Comparison of prehospital stroke assessment scales in the study population

Item	C-STAT (%)	FAST-ED (%)	LAMS (%)	PASS (%)	RACE (%)	3-Items (%)	ACT-FAST (%)	VAN (%)	Tzu Chi (%)	Tzu Chi (modified) (%)
Overall										
Sensitivity	58.14	67.44	67.44	67.44	62.79	34.88	67.44	76.74	58.14	74.42
Specificity	86.57	83.58	88.06	80.60	86.57	95.52	89.55	80.60	92.54	76.12
PPV	73.53	72.50	78.38	69.05	75.00	83.33	80.56	71.74	83.33	66.67
NPV	76.32	80.00	80.82	79.41	78.38	69.57	81.08	84.38	77.50	82.26
Accuracy	75.45	77.27	80.00	75.45	77.27	71.82	80.91	79.09	79.09	75.45
Anterior										
Sensitivity	63.64	78.79	72.73	75.76	69.70	39.39	78.79	87.88	63.64	78.79
Specificity	83.12	81.82	83.12	77.92	83.12	93.51	87.01	77.92	88.31	71.43
PPV	61.76	65.00	64.86	59.52	63.89	72.22	72.22	63.04	70.00	54.17
NPV	84.21	90.00	87.67	88.24	86.49	78.26	90.54	93.75	85.00	88.71
Accuracy	77.27	80.91	80.00	77.27	79.09	77.27	84.55	80.91	80.91	73.64
Posterior										
Sensitivity	40.00	30.00	50.00	40.00	40.00	20.00	30.00	40.00	40.00	60.00
Specificity	70.00	63.00	68.00	62.00	68.00	84.00	67.00	58.00	74.00	58.00
PPV	11.76	7.50	13.51	9.52	11.11	11.11	8.33	8.70	13.33	12.50
NPV	92.11	90.00	93.15	91.18	91.89	91.30	90.54	90.63	92.5	93.55
Accuracy	67.27	60.00	66.36	60.00	65.45	78.18	63.64	56.36	70.91	58.18

ACT-FAST: The 3-step ambulance clinical triage for acute stroke treatment algorithm, C-STAT: Cincinnati stroke triage assessment tool, FAST-ED: Field assessment stroke triage for emergency destination, LAMS: Los Angeles Motor Scale, NPP: Negative predictive value, PASS: Prehospital Acute Stroke Severity Scale, PPV: Positive predictive value, RACE: Rapid Arterial oCclusion Evaluation Scale, Tzu Chi: Tzu Chi Stroke Severity Scale, VAN: Vision Aphasia Neglect, 3-items: 3-Item Stroke Scale

Table 6: The original versus optimal cutoff for prehospital stroke assessment assessment scales, which utilize numerical score systems

Prehospital stroke assessment scales	Original cut-off values	Optimal cut-off values	Sensitivity (of original vs. optimal cut-off values)	Specificity (of original vs. optimal cut-off values)
Overall				
C-STAT	≥2	≥2	58.14	86.57
FAST-ED	≥4	≥3*	67.44 versus 81.40	83.58 versus 76.12
LAMS	≥4	≥4	67.44	88.06
PASS	≥2	≥2	67.44	80.60
RACE	≥5	≥4*	62.79 versus 74.42	86.57 versus 82.09
3-Items	≥4	≥2*	34.88 versus 72.09	95.52 versus 77.61
Anterior				
C-STAT	≥2	≥2	63.64	83.12
FAST-ED	≥4	≥3*	78.79 versus 90.91	81.82 versus 72.73
LAMS	≥4	≥3*	72.73 versus 84.85	83.12 versus 72.73
PASS	≥2	≥2	75.76	77.92
RACE	≥5	≥4*	69.70 versus 81.82	83.12 versus 77.92
3-Items	≥4	≥2*	39.39 versus 78.79	93.51 versus 74.03
Posterior				
C-STAT	≥2	≥2	40.00	70.00
FAST-ED	≥4	≥3*	30.00 versus 50.00	63.00 versus 54.00
LAMS	≥4	≥4	50.00	68.00
PASS	≥2	≥2	40.00	62.00
RACE	≥5	≥4*	40.00 versus 50.00	68.00 versus 61.00
3-Items	≥4	≥1*	20.00 versus 70.00	84.00 versus 40.00

*Optimal cut-off values according to our data. C-STAT: Cincinnati stroke triage assessment tool, FAST-ED: Field assessment stroke triage for emergency destination, LAMS: Los Angeles Motor Scale, PASS: Prehospital Acute Stroke Severity Scale, RACE: Rapid Arterial oCclusion Evaluation Scale, 3-items: 3-Item Stroke Scale

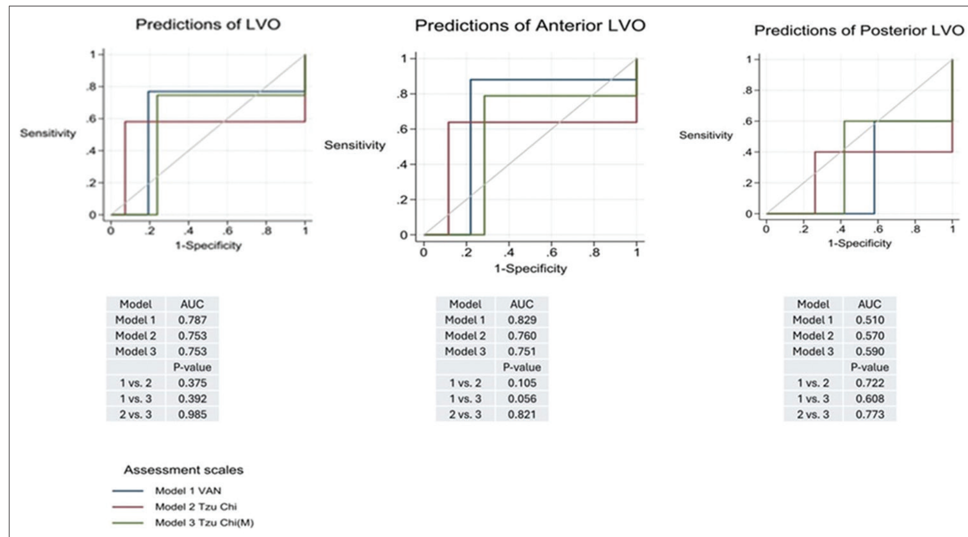

Figure 2: The receiver operating characteristic (ROC) curves comparing the Vision Aphasia Neglect (VAN) scale, Tzu Chi stroke severity scale, and its modified version demonstrated comparable discrimination ability for detecting large vessel occlusion. The patients in our study population are already confirmed to have acute stroke symptoms. Hence, in our study, the ROC curve analysis of VAN, Tzu Chi stroke severity scale, and its modified version did not include the items of the first step to screen for acute stroke symptoms. Tzu Chi: Tzu Chi stroke severity scale, Tzu Chi (M): modified Tzu Chi stroke severity scale, VAN: Vision aphasia neglect scale

scale ranges from 100% to 79% depending on the regional context [26,27]. Most prehospital stroke scales are consistently insensitive for posterior circulation stroke [28].

In our retrospective study, the VAN scale emerged as the most sensitive (76.74%) for detecting LVO. However, the identification of "neglect/hemineglect" using the VAN scale is susceptible to interrater variability. Furthermore, most EMT staff in our region are not trained to detect "neglect," thereby limiting the practicality of implementing the VAN scale. VAN scale also had poor sensitivity (40%) for posterior circulation stroke.

Our Tzu Chi stroke severity stroke scale demonstrated modest sensitivity (58.14%) and higher specificity (92.54%). However, if we used a modified version by lowering the

Table 7: The number and distribution of the components of the Tzu Chi stroke severity scale related to the number and distribution of intracranial large vessel occlusion in our study

Distribution of radiologically confirmed LVO	Number	Components of the Tzu Chi		
		Altered level of consciousness	Conjugate eye deviation	No antigravity in muscle strength of the upper and/or lower limbs
Right anterior circulation				
ACA	0	0	0	0
MCA M1	12	7	7	9
MCA M2	2	0	1	2
ICA	8	3	5	6
Left anterior circulation				
ACA	0	0	0	0
MCA M1	6	2	3	4
MCA M2	2	0	0	0
ICA	3	3	3	3
Posterior circulation				
BA	8	2	3	5
Left VA	2	1	0	0
Right VA	0	0	0	0
Total cases	43	18	22	29

ACA: Anterior cerebral artery, BA: Basilar artery, ICA: Internal carotid artery, LVO: Large vessel occlusion, MCA M1: M1 segment of middle cerebral artery, MCA M2: M2 segment of middle cerebral artery, VA: Vertebral artery, Tzu Chi: Tzu Chi Stroke Severity Scale

cutoff threshold, the sensitivity became higher to 74.42%. We compared the discriminatory power of VAN, which has the highest sensitivity with original cutoff values, with Tzu Chi scales. The study results and AUC values underscored the comparable effectiveness of the modified Tzu Chi scale and VAN scale in identifying LVO, highlighting the potential utility of the modified version in the prehospital setting. Moreover, the items of the modified Tzu Chi stroke severity scale are easier to practice than VAN for EMT staff in our region. Our study also suggests lower cutoff values are needed if FAST-ED, RACE, and 3-item scales are intended to be used in our regions, but their specificity will be affected [Table 6]. After lowering the cutoff values, FAST-ED and RACE performed slightly better than the modified Tzu Chi scale, particularly in detecting anterior circulation LVO. However, like the VAN scale, they are less sensitive than the modified Tzu Chi scale for posterior circulation LVO. Again, implementing these scales is impractical without proper training of EMT staff to assess neglect/agnosia. The 3-item scale would also require significant cutoff adjustments, especially for posterior circulation, to be effective in our region, and the modified Tzu Chi scale still showed higher sensitivity than the 3-item scale with lowered cutoffs.

In our study, the modified Tzu Chi scale also showed the highest sensitivity (60%) for posterior circulation strokes. Although it is important to recognize that every LVO prediction triage system will inevitably miss some patients with LVO and milder strokes [29], for instance, checking for an altered level of consciousness in the Tzu Chi scale is insensitive to occlusion in the more distal part of large vessels such as M2 branch of middle cerebral arteries, but they still prove effective in shortening prehospital onset-to-door time. For instance, implementing the C-STAT would increase the transport of suspected stroke cases to the comprehensive medical center by 11% within 6 hours and 21% within 24 hours [8].

It is worthnoting that even if a patient exhibiting acute stroke symptoms and positive LVO screening results is eventually diagnosed with a hemorrhagic stroke rather than an ischemic one, the benefits of receiving neurointensive care in a tertiary center remain significantly beneficial to the patients. Recently, tertiary centers such as ours implemented AI-generated neuroimaging protocols. Integrating efficient prehospital screening tools and AI-generated neuroimaging shows promise for the early detection of LVO and decision-making in comprehensive stroke care [30]. Our study's limitations include a single-center design and a relatively small sample size. The current sample size may be enough to estimate AUC for predicting overall LVO and anterior LVO but not for posterior LVO. Data were retrospectively reviewed based on the medical records and NIHSS conducted by neurologists during admission, whereas prehospital assessments were intended to be performed by EMT staff. This may introduce interrater variability.

Conclusions

Our findings support the transition to use the modified Tzu Chi stroke severity scale, which shows feasibility and better sensitivity for both anterior and posterior circulation LVO in the EMS transfer algorithm for LVO detection in Eastern Taiwan. Among the established prehospital scales, FAST-ED and RACE, with adjusted optimal cutoff values for the study population of our region, showed slightly better overall diagnostic accuracy than the modified Tzu Chi scale. However, they still exhibit poor sensitivity in detecting posterior circulation LVO. In addition, implementing these scales in our region would require extensive training of all EMT personnel to detect neglect/agnosia, which could demand significant resources.

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Data availability statement

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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Appendix

Appendix 1: The detailed description related to the area under curve (AUC) values and sample size for acute stroke with large vessel occlusion (LVO)

Model 1 stands for Vision Aphasia Neglect scale (VAN).

Model 2 stands for the Tzu Chi stroke severity scale.

Model 3 stands for the modified Tzu Chi stroke severity scale.

The receiver operating characteristics (ROC) curves comparing the aforementioned models are shown in Figure 1.

1. For anterior circulation, the AUC for Model 1 was 0.829, whereas for Model 3, it was 0.751, suggesting that Model 1 might perform better in predicting anterior LVO. However, the 95% confidence intervals for the AUCs of Model 1 and Model 3 were (0.744 and 0.914) and (0.651 and 0.851), respectively. Since these intervals largely overlap, the difference in performance may not be statistically significant
2. Among the LVO patients, 10 (23%) of them were posterior LVO, whereas 33 (77%) were anterior LVO. Posterior LVO were less common. We performed sample size estimation for three conditions below:
   i. Condition I: Overall
   We set Area under ROC curve = 0.7, null hypothesis AUC value = 0.5, prevalence = 0.39 (=43/110), $\alpha = 0.05$, and power $(1-\beta) = 0.80$. Then, the sample size needed was at least 67.
   ii. Condition II: Anterior LVO
   We set Area under ROC curve = 0.7, null hypothesis AUC value = 0.5, prevalence = 0.30 (=33/110), $\alpha = 0.05$, and power $(1-\beta) = 0.80$. Then, the sample size needed was at least 72.
   iii. Condition III: Posterior LVO
   We set area under ROC curve = 0.7, null hypothesis AUC value = 0.5, prevalence = 0.09 (=10/110), $\alpha = 0.05$, and power $(1-\beta) = 0.80$. Then, the sample size needed was at least 158.
   Thus, the current sample size ($n = 110$) may be enough for estimating AUC for predicting overall LVO and anterior LVO, but not for posterior LVO.