

Systematic Review

Comparison of Prehospital Diagnostic Scores for Identifying Large Vessel Occlusions: A Systematic Review and Meta-Analysis

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Abstract

Introduction: Stroke remains the second leading cause of death worldwide and a major cause of long-term disability. Approximately 87% of strokes are ischemic, and 30% of these are large vessel occlusions (LVOs). Early recognition of LVOs and rapid transport to a comprehensive stroke center (CSC) capable of MT are critical to improving outcomes. Accurately predicting LVOs in prehospital settings remains challenging. Several triage scales have been developed to aid early detection, but their diagnostic accuracy varies across studies. This study compares the performance of commonly used prehospital LVO scales by pooling published data to identify which tools best support emergency medical services (EMS) in optimizing triage and improving outcomes. **Methods:** A systematic search, following the Cochrane Library, of PubMed, Scopus, and Web of Science identified studies evaluating prehospital LVO triage scales using standardized search terms. Diagnostic accuracy measurements were extracted, and a pooled analysis was completed to compare scores. **Results:** From 743 unique articles, 15 studies evaluating prehospital large vessel occlusion (LVO) triage scales were included. Pooled log diagnostic odds ratios (DORs) indicated that RACE demonstrated the highest discriminative performance (2.367 [1.943–2.792]), followed by LAMS (2.228 [1.987–2.470]). The lowest scores were from the PASS (1.992 [1.758–2.227]) and C-STAT (1.886 [1.652–2.119]) scales. **Conclusions:** Among prehospital triage scales, RACE demonstrated the highest accuracy for LVO detection, followed by LAMS and G-FAST. Variation in scores may indicate inconsistency in performing the tests or the complexity of the questions. These findings support a personalized approach to choosing an LVO identification scale based on the resources available.



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1. Introduction

Worldwide, there are approximately 11.9 million new stroke events annually [1], and strokes are responsible for 160.4 million disability-adjusted life-year counts each year [2]. In total, 87% of stroke events are ischemic, with large vessel occlusions (LVOs) making up approximately 30% of these [3,4]. This is substantial since LVOs should be treated with mechanical thrombectomy (MT) if the patient presents within 24 h of symptom onset, while

tissue plasminogen activator (tPA) can be used to treat all ischemic strokes within 4.5 h [5]. It has been reported that for every second delay in MT treatment, there is a decrease in healthy life expectancy of 2.2 h [6].

Since tPA treatment is time dependent and MT treatment requires a comprehensive stroke center (CSC) [7], triage of patients to the most appropriate location for treatment is completed by members of the emergency medical transport team. This initial evaluation allows patients to be directed to a CSC when LVO is suspected, even if they could reach a peripheral stroke center (PSC) sooner. This transport method is called bypass transport [8,9]. Prehospital diagnosis of LVOs can help improve transport efficiency based on these methods. However, correctly predicting whether or not a patient has an LVO in a prehospital setting remains challenging, and several scales have been developed to assist in early identification of LVO [10]. While several scales have been proposed and tested, they may vary in complexity, completion time, and the need for training [10]. This has caused an inconsistency in terms of which scale is best used. Additionally, a prior review has reported that patients that tested negative could still have a greater than 10% probability of an LVO [11]. Additionally, none of the current studies reflect on how the country of the study may impact scale accuracy.

This study utilizes the scale metrics (sensitivity, specificity, and area under the curve (AUC)) previously reported and completed a meta-analysis to compare the ability of several prehospital scales to identify LVOs. We also explore how these results may vary based on the country in which the study was conducted. By systematically evaluating the accuracy of LVO prediction for each scale, we aim to clarify which scales may best support emergency medical services (EMS) in improving triage decisions and, ultimately, patient outcomes post LVO.

2. Methods

2.1. Search and Quality Assessment

Following the Cochrane Library and 2020 PRISMA guidelines (Supplementary Materials, Tables S1 and S2) [12,13], a systematic search was conducted utilizing PubMed, Scopus, and Web of Science. The search terms included (“prehospital” OR “triage” OR “transport”), (“large” AND “vessel” AND “occlusion” OR “stroke”) and (“assessment” OR “scale” OR “score”). Two authors independently screened the articles for inclusion. This protocol was registered under PROSPERO ID: CRD420251143247. Articles were included if they reported the test metrics for a scale’s ability to identify LVOs in the prehospital setting. Exclusion criteria included case reports, literature reviews, and papers that used only simulated data. Following article selection, each was graded according to the Quality Assessment of Diagnostic Accuracy Studies (QUADAS-2) tool to assess bias [14]. According to this scoring system, four domains (patient selection, index test, reference standard, and flow and timing) were rated based on risk of bias. Each domain could be categorized as “high”, “low”, or “unclear”.

2.2. Variables and Outcomes

Data were extracted for each article. This included the total number of participants, sensitivity, specificity, and AUC for each scale within the article. Additionally, the country of the study, setting of the study, mean patient age, proportion of female patients, and number of patients with hypertension (HTN), atrial fibrillation (Afib), and diabetes mellitus (DM) were collected. From the test metrics, we calculated the primary outcomes, including the number of true positives, true negatives, false positives, and false negatives.

2.3. Statistical Analysis

From the articles, we included the outcomes for 8 different scales: the Rapid Arterial Occlusion Evaluation (RACE), Cincinnati Prehospital Stroke Severity Scale (CPSS), Los Angeles Motor Scale (LAMS), Prehospital Acute Stroke Severity (PASS), Gaze-Face-Arm-Speech-Time (G-FAST), Conveniently-Grasped Field Assessment Stroke Triage (CG-FAST), Cincinnati Stroke Triage Assessment Tool (C-STAT), and Face-Arm-Speech-Time-PLUS (FAST-PLUS). Using the number of true positives, true negatives, false positives, and false negatives for each scale, we calculated pooled log diagnostic odds ratios (DORs). Additionally, the pooled AUC was calculated for scales that had at least four unique studies. For these scales with at least four studies, a univariable regression analysis was completed comparing the log DORs to patient age, proportion of females, studies within the United States of America (USA), and proportion of comorbidities. We could not complete these analyses for scales with fewer articles due to the limited data available with fewer than four studies. All analyses were completed in R version 4.4.2 using the packages metafor and mada. A *p*-value of 0.05 was used for statistical significance.

3. Results

3.1. Study Selection

From 743 unique articles, 14 fit the inclusion criteria (Figure 1 and Table 1) [15–28]. However, Ali et al. reported on two separate patient populations (one that was all female and one that was all male); therefore, there were 15 patient populations studied across all articles. There were 13,810 patients included, and 50.1% of the participants were female. The proportion of participants with hypertension, atrial fibrillation, or diabetes mellitus was reported in four, five, and five populations, respectively. There were eight different stroke scoring systems that were evaluated in these studies. A comparison of the scales is demonstrated in Table 2. Of the included studies, the same scoring cutoff was used between studies for each individual scale. The most common evaluated scores were RACE and CPSS in six publications each. Five of the patient populations were based in the United States, while four were in The Netherlands. The rest were in another European country or Japan (Table 1).

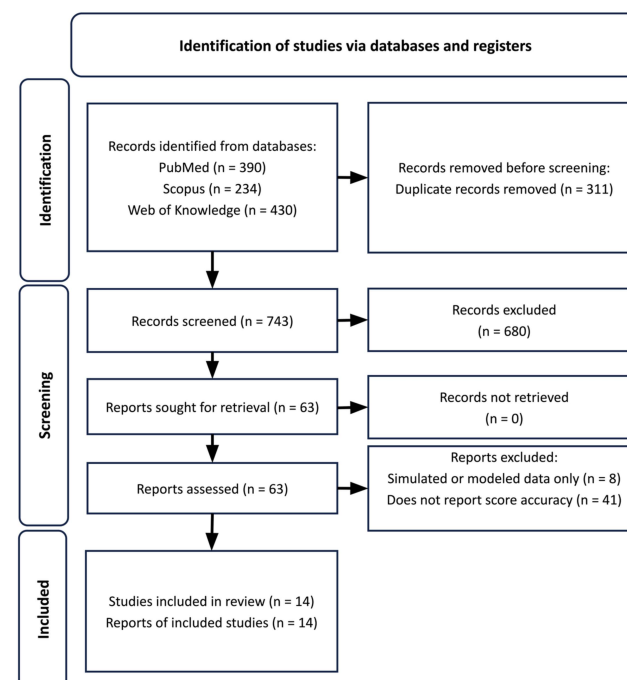


Figure 1. PRISMA diagram of included articles.

Table 1. Metrics for each score in each of the included studies.

Study	Country	Total N	Scale	Sensitivity	Specificity	Risk of Bias (Selection/Test/Standard/Flow)
Glober et al. 2022 [15]	USA	106	RACE	0.71	0.57	Low/Low/Low/Low
Krebs et al. 2022 [16]	Austria	307	RACE CPSS APSShand	0.91 0.86 0.9	0.79 0.8 0.79	Low/Low/Low/Low
Nehme et al. 2019 [17]	USA	376	CPSS	0.88	0.48	Low/Low/Low/Low
Duvekot et al. 2021 [18]	The Netherlands	1039	RACE G-FAST CG-FAST LAMS CPSS PASS C-STAT FAST-PLUS	0.67 0.67 0.5 0.63 0.57 0.59 0.5 0.6	0.87 0.82 0.89 0.84 0.85 0.83 0.85 0.83	Low/Low/Low/Low
Ali et al. 2024 [19]	The Netherlands	1114 (female only)	LAMS RACE C-STAT CPSS PASS G-FAST CG-FAST FAST-PLUS	0.76 0.68 0.63 0.59 0.65 0.7 0.53 0.64	0.79 0.84 0.8 0.84 0.8 0.8 0.87 0.82	Low/Low/Low/Low
		1244 (male only)	LAMS RACE C-STAT CPSS PASS G-FAST CG-FAST FAST-PLUS	0.63 0.62 0.62 0.51 0.59 0.63 0.49 0.54	0.82 0.82 0.82 0.88 0.84 0.83 0.9 0.86	
Dickson et al. 2019 [20]	USA	440	RACE	0.66	0.72	Low/Low/Low/Low
Mazya et al. 2020 [21]	Sweden	2905	SSTS	0.42	0.93	Low/Low/Low/Low
Nishiwaki et al. 2024 [22]	Japan	109	CPSS CPSS+JUST	0.34 0.55	0.89 0.7	Low/Low/Low/Low
Dekker et al. 2023 [23]	The Netherlands	1565	RACE	0.58	0.91	Low/Low/Low/Low
Mohamed et al. 2022 [24]	USA	907	CPSS	0.76	0.72	Low/Low/Low/Low
Helwig et al. 2019 [25]	Germany	116	LAMS	0.78	0.71	Low/Low/Low/Low
Takahashi et al. 2024 [26]	Japan	351	ELVO	0.87	0.47	Low/Low/Low/Low
Panichpisal et al. 2022 [27]	USA	326	SNOW	0.88	0.4	Low/Low/Low/Low
Keselman et al. 2022 [28]	Sweden	2905	SSTS	0.71	0.91	Low/Low/Low/Low

Table 2. Aspects of the assessment included in the three most common scores of this article, indicated by a “X”.

Metrics Evaluated	RACE	CPSS	LAMS
Facial Droop	X	X	X
Arm Motor Weakness	X	X	X
Leg Motor Weakness	X		
Speech/Aphasia		X	
Grip Strength			X
Gaze Deviation	X		
Agnosia/Neglect	X		

3.2. Comparison of Scoring Systems

After pooling the studies, the heterogeneity metrics (Cochran's Q : 48.772, p = 0.113, I^2 = 22.086%) indicate that the included studies are relatively consistent [29]. The pooled log DORs were calculated for each score based on the studies that reported results (Figure 2). We found that RACE demonstrated the highest discriminative performance (2.367 [1.943–2.792]), followed by LAMS (2.228 [1.987–2.470]). The lowest scores were from the PASS (1.992 [1.758–2.227]) and C-STAT (1.886 [1.652–2.119]) scales. The SROC of studies that use the RACE, CPSS, and LAMS scoring is shown in Figure 3. Based on these results, the RACE scoring has the best sensitivity to false positive rate overall (AUC = 0.826), but it also has the greatest variability, represented by the confidence interval.

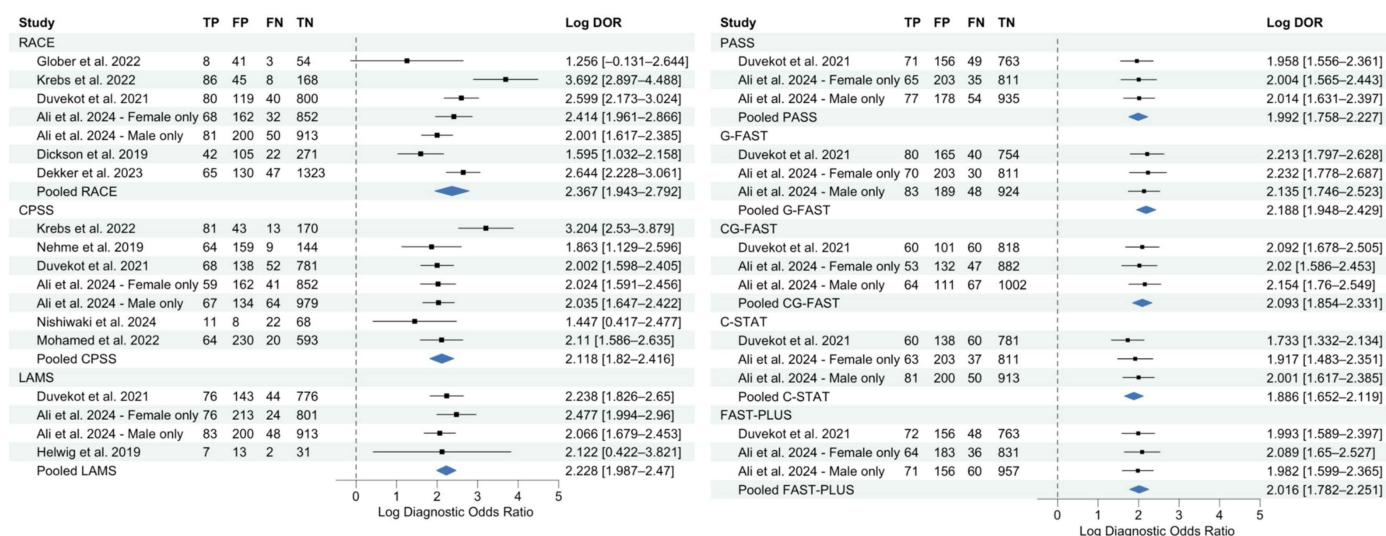


Figure 2. Forest plot showing the log diagnostic odds ratio for each score [15–28]. The blue rhombus represents the confidence interval for the pooled log diagnostic odds ratio. TP = true positive; FP = false positive; FN = false negative; TN = true negative; DOR = diagnostic odds ratio.

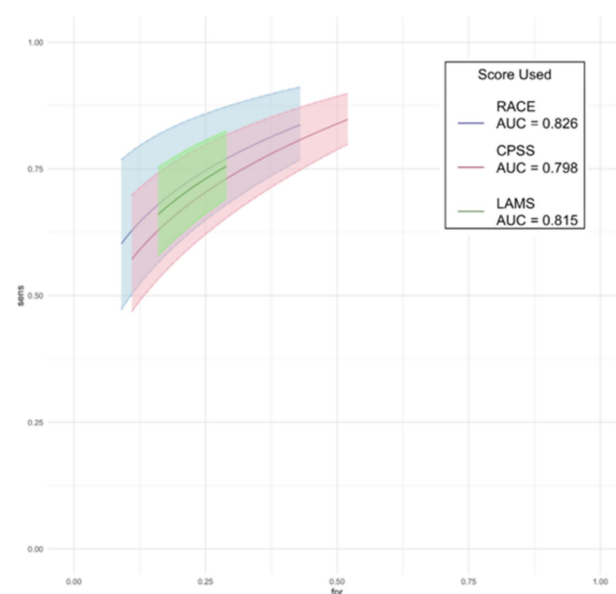


Figure 3. Pooled area under the curve of the score. The shaded region in each color represents the 95% confidence interval. Sens = sensitivity; fpr = false positive rate; AUC = area under the curve.

3.3. Factors Affecting Accuracy

A univariable analysis was completed comparing the patient and study demographics to the log DOR, and the results are reported in Table 3. For studies that test the RACE scoring system, the articles published in the United States were significantly associated with worse diagnostic capability than those in the other countries (p -value = 0.048). No variables were significantly associated with the outcome in the CPSS scoring system; however, age was the most substantial factor whereas studies that had a greater mean age had a worse diagnostic metric (p -value = 0.057). A greater proportion of female participants was associated with better diagnostic metrics for articles published with the LAMS scoring system (p -value = 0.017).

Table 3. Univariable analysis of each score with variables of interest. HTN = hypertension; Afib = atrial fibrillation; DM = diabetes mellitus; * = statistically significant (p -value < 0.05).

	RACE			CPSS			LAMS		
	Coefficient	Standard Error	p -Value	Coefficient	Standard Error	p -Value	Coefficient	Standard Error	p -Value
Publication Year	0.094	0.197	0.653	−0.036	0.126	0.785	0.027	0.049	0.640
USA Study	−1.245	0.476	0.048 *	−0.156	0.486	0.761	NA	NA	NA
Mean Age	−0.178	0.483	0.731	−0.355	0.117	0.057	−0.038	0.096	0.728
Proportion Female	0.449	1.083	0.700	0.149	1.039	0.895	0.428	0.056	0.017 *
Proportion HTN	8.880	8.408	0.483	−0.630	0.231	0.224	0.585	1.093	0.535
Proportion Afib	7.785	11.480	0.568	−0.588	0.717	0.562	−2.116	6.792	0.785
Proportion DM	2.767	5.278	0.652	1.120	1.341	0.557	0.954	3.676	0.820

4. Discussion

With improved treatment options for ischemic strokes and LVOs, early identification and efficient transport have become major factors in improving patient care. One aspect of this is prehospital triage in identifying patients that are suspected to have an LVO since greater diagnostic accuracy improves transport efficiency. This meta-analysis compares the diagnostic accuracy of eight prehospital scales in identifying LVOs in order to inform emergency medical services to transport the patient to a CSC capable of MT. Based on the pooled log DOR, the RACE scale demonstrated the highest discriminative capability, followed by LAMS and G-FAST. This finding is consistent with other work showing that the RACE scale performed mildly better than other prehospital assessments [18]. However, the RACE scale also had the widest variability between studies. This may be due to the added complexity of the questions, since there are commonly three choices depending on deficit severity as opposed to a binary option. Prior reviews have recommended that a simple yes/no scoring system be used to reduce subjective variability [10]. Other scales in this analysis that use binary scoring are the PASS, C-STAT, and G-FAST scales. While the subjective bias may be reduced with training, this added barrier to implementation may discourage different transport systems from implementing the RACE scale compared to those with a binary scoring system.

In addition to variability introduced by the examiners, diagnostic accuracy may change based on patient demographic and test location. In the univariable analysis completed, we found that the RACE scale had a lower log DOR in studies that were completed in the United States compared to those that were not (p -value < 0.05). This may be due to

differences in training around the use of this system based on country location. It may also allude to the impact that the setting has on accuracy, since emergency transport in the United States may have to cover larger areas spanning urban and rural locations [9]. In other stroke scales, we saw significant relationships between log DOR and patient demographics. The LAMS scale had higher diagnostic capabilities in participant populations with a higher proportion of females. While the impact of gender was explored by Ali et al. 2024, they found that the LAMS scale accuracy was not significantly different between males and females [19]. Due to these inconsistent results, a larger study should be conducted to investigate this relationship. Although insignificant (p -value = 0.57), there was a trend of higher log DORs in younger populations for the CPSS scale. While analysis with the other scales was not completed due to the limited number of studies that used them, it is likely that other correlations would be found between log DOR, environmental setting, and patient demographics. Therefore, more comprehensive investigations should be completed to examine and correct these relationships. Additionally, these factors should be taken into account prior to scale selection for a given transport service.

4.1. Clinical Application

Our results demonstrate that while the RACE scale had the greatest performance across these studies, the difference was not substantial and there was a large amount of variation. Additionally, there are concerns about how the amount of time taken to complete the assessment and the complexity of questions impact patient transport and outcomes [10]. In addition to added complexity, the RACE scale has five questions instead of the three to four questions used in other scales [30]. Although none of the studies in this analysis reported the amount of time that the evaluation took, it is reasonable to assume that this can vary based on the scale used and that it could delay treatment. While some of this variation can be controlled for with training, we also noted that geographical location and patient demographic correlated with differences in the diagnostic ability of the scales. Therefore, specific population factors should be considered when choosing a prehospital scale to use. Due to differences in resources and locations, we suggest that each emergency medical transport system evaluate which assessment is appropriate for their particular patient population.

4.2. Limitations

Although this is a needed review of the prehospital scales and the first study that examines how location may correlate with accuracy, there are some limitations that affect how these findings can be applied. The first limitation is that by the design of this review, we only include published full-text articles that are available in English. By selection bias, we could be missing data, especially studies that may not have found findings sufficiently significant to be published. We also relied on consistent reporting across studies. Not all studies reported on patient demographics; therefore, they could not be included in the univariable analysis. Additionally, there are several articles that do not report the outcome metrics of the scales they used, limiting our ability to assess their accuracy in these studies. The limited number of studies that could be included in the analysis cause the models to be unstable, and we were unable to complete more comprehensive statistical analyses due to this. Future work should be conducted to further explore the relationship demonstrated in these results.

Another limitation is that not all scales are included in this study, since several scales are not widely published on. Therefore, newer or more obscure scales cannot be compared to those discussed in this study. The studies included in this review were published in only a small subset of countries, limiting the generalizability of these results to different

areas. Finally, the studies included here do not discuss how the triage team was trained. Since these scales vary in complexity, proper training may improve the accuracy. Since this information is not available in the majority of studies, we cannot comment on how training can impact the outcome mentioned here. Future work should report on the training regimen as well as the time to complete these scales to allow for a more comprehensive comparison. These studies should also be conducted and compared across a larger number of countries.

5. Conclusions

Our results show that the RACE prehospital stroke scale has the highest diagnostic accuracy but may not be universally optimal due to the impact of demographic and geographic variables. Therefore, EMS should choose a stroke scale that considers the local stroke population, transport time, and personnel training. In doing so, they can optimize the time necessary to transport an LVO patient to a CSC to receive optimal care and improve outcomes.

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/ecm3010006/s1>, Table S1: PRISMA abstract checklist [12]; Table S2: PRISMA main text checklist [12].

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