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The Cincinnati Prehospital Stroke Scale Can Identify Large Vessel Occlusion Stroke

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Abstract

Objective: Accurate prehospital identification of patients with acute ischemic stroke (AIS) from large vessel occlusion (LVO) facilitates direct transport to hospitals that perform endovascular

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thrombectomy. We hypothesize that a cut-off score of the Cincinnati Prehospital Stroke Scale (CPSS), a simple assessment tool currently used by emergency medical services (EMS) providers, can be used to identify LVO.

Methods: Consecutively enrolled, confirmed AIS patients arriving via EMS between August 2012 and April 2014 at a high-volume stroke center in a large city with a single municipal EMS provider agency were identified in a prospective, single-center registry. Head and neck vessel imaging confirmed LVO. CPSS scores were abstracted from prehospital EMS records. Spearman's rank correlation, Wilcoxon rank-sum test, and Student's t-test were performed. Cohen's kappa was calculated between CPSS abstractors. The Youden index identified the optimal CPSS cut-off. Multivariate logistic regression controlling for age, sex, and race determined the odds ratio (OR) for LVO.

Results: Of 144 eligible patients, 138 (95.8%) had CPSS scores in the EMS record and were included for analysis. The median age was 69 (IQR 58–81) years. Vessel imaging was performed in 97.9% of patients at a median of 5.9 (IQR 3.6–10.2) hours from hospital arrival, and 43.7% had an LVO. Intravenous tissue-type plasminogen activator was administered to 29 patients, in whom 12 had no LVO on subsequent vessel imaging. The optimal CPSS cut-off predicting LVO was 3, with a Youden index of 0.29, sensitivity of 0.41, and specificity of 0.88. The adjusted OR for LVO with CPSS=3 was 5.7 (95% CI 2.3–14.1). Among patients with CPSS=3, 72.7% had an LVO, compared with 34.3% of patients with CPSS≤2 ($p<0.0001$).

Conclusions: A CPSS score of 3 reliably identifies LVO in AIS patients. EMS providers may be able to use the CPSS, a simple, widely adopted prehospital stroke assessment tool, with a cut-off score to screen for patients with suspected LVO.

Keywords

Stroke; Prehospital Emergency Care; Brain Infarction; Emergency Medical Services; Emergency Medical Technicians

Introduction

Endovascular thrombectomy (EVT), in addition to intravenous tissue plasminogen activator (IV tPA), improves outcomes for patients with acute ischemic stroke (AIS) caused by large vessel occlusion (LVO) if performed quickly after symptom onset.[1–5] EMS detection of stroke is associated with improved stroke quality metrics and improved stroke outcomes.[6–14] Identifying patients with suspected LVO in the prehospital setting by EMS providers can result in preferential transport to comprehensive stroke centers (CSC) that perform EVT for eligible AIS patients with LVO.[15–19]

Prehospital assessment tools have been developed to screen for LVO.[11,15,20–30] However, most prehospital LVO screening tools involve a physical examination based on the National Institute of Health Stroke Scale (NIHSS) assessment, which presents education and reproducibility challenges for emergency medical services (EMS) providers.[11] Additionally, prehospital screening tools that have high sensitivity may result in over-triaging of patients without LVO to CSCs, which could lead to longer transport times, delays in IV tPA administration for patients who are ultimately not eligible for EVT, and longer out of service times for ambulances.[31] Screening tools that have high specificity will not detect some patients with LVO, resulting in transport of patients with LVO to non-CSCs who then require subsequent inter-facility transport to CSCs, a time-consuming process that may disqualify otherwise eligible patients from receiving EVT.[32,33] Lastly, implementation of any new prehospital assessment tool into an EMS system must overcome a significant educational burden prior to adoption by EMS providers.[26,34]

The Cincinnati Prehospital Stroke Scale (CPSS) is a validated prehospital stroke screening tool that has been easily and widely adopted by all levels of EMS providers.[35] The CPSS is scored from 0 to 3, with one point given for each of the following physical exam findings: facial droop, arm drift, and slurred speech.[35] A prior study in South Korea found that a prehospital CPSS cut-off score of 2 predicts thrombolysis in patients with AIS after emergency department (ED) arrival.[36] However, the CPSS has not been evaluated as a screening tool for LVO. Given the wide adoption of the CPSS, its simplicity, and minimal training requirements, we hypothesize that a cut-off score of the CPSS that predicts LVO can be identified.

Methods

Study Design and Setting

A retrospective analysis was performed of consecutively enrolled, confirmed AIS patients in the Northwestern University Brain Attack Registry who were admitted to a single, high-volume CSC, as previously described.[37] During the study period, a single municipal EMS provider agency responded to all 9–1-1 calls in the study site's city, and we identified the subset of registry patients who arrived to the study CSC via EMS. EMS protocols instructed paramedics to use the CPSS to evaluate patients with suspected stroke. Patients with abnormal CPSS scores (i.e., scored as ≥1) and symptoms known to have started within 6 hours of paramedic arrival were transported to the closest primary stroke center (PSC). Additionally, patients with sudden and persistent alteration of consciousness, sudden severe headache with hypertension or vomiting, or severe and sudden loss of balance were also transported to PSCs. At the time of the study, prehospital LVO screening was not being performed, and no protocols to bypass PSCs and directly transport patients with severe stroke syndromes to CSCs were being used. For patients with an abnormal CPSS, EMS providers were instructed to pre-notify the receiving stroke center.

Study Population

Patients transported by EMS to the study hospital ED between August 2012 and April 2014 were included for analysis. The diagnosis of AIS was confirmed by magnetic resonance imaging (MRI) or, in the event that a patient had a contraindication to MRI, by computed tomography (CT). Diagnosis of AIS was adjudicated by 2 board-certified stroke attending neurologists.[37] Admitted patients who had initially arrived via EMS for a non-stroke complaint but later had an AIS with symptoms documented to have started after admission to the hospital as an inpatient were excluded from analysis.

Age, sex, initial NIHSS score, prior medical history, time of symptom onset, ED arrival time, reperfusion therapy(s), and patient outcome were prospectively collected in the registry.[37] The CPSS score was abstracted by two independent abstractors (CTR, RH) from the EMS run report using all available fields in the EMS electronic medical record (EMR), which included the “neurologic exam” field, general exam field, and free-text narrative field for CPSS exam findings. If any of the three physical exam elements of the CPSS were not clearly documented in the EMS EMR, the element was scored as 0. However, if none of the three elements of the CPSS were able to be abstracted from the EMS EMR, the case was excluded from the analysis. In instances where the CPSS improved during the course of prehospital care, the highest CPSS score (i.e., most profound prehospital deficit) was used for analysis. Disagreements were resolved by consensus.

Outcomes

The primary outcome was the presence of LVO on head and neck vessel imaging using the first completed radiology study including: MRI angiography, CT angiography, conventional angiography, or ultrasound duplex. The presence of an LVO on first vascular imaging study was rated by two study team members (CTR, SP) blinded to the prehospital data. LVO was defined as near complete or complete occlusion of the following arteries: intracranial internal carotid artery, middle cerebral artery M1 or M2 segments, anterior cerebral artery A1 segment or proximal A2 segment, basilar artery, posterior cerebral artery P1 or P2 segments, or intracranial vertebral artery.[38] Any disagreements were resolved by consensus.

Secondary outcomes included initial stroke severity and receipt of reperfusion therapy. The initial NIHSS score upon patient arrival to the ED, as documented by the stroke neurology physician, was used as a marker for stroke severity. NIHSS scores of 10 and 15 were used as additional stroke severity outcomes because an NIHSS score ≥ 10 is associated with LVO and because an NIHSS score ≥ 15 is a cut-off for considering hemicraniectomy after AIS.[39,40] Reperfusion therapy was defined as having received IV tPA, EVT, or attempted EVT.

Analytical Methods

The Spearman’s rank test was performed for correlation after skewness and kurtosis tests were performed to evaluate for the presence of non-normally distributed data. Descriptive statistics were performed for the demographic data, Student’s t-test was used to compare proportions, and the Wilcoxon rank-sum test was used to compare medians. The Youden index was performed to identify the optimal cut-off scores for the CPSS.[41,42] A receiver operating characteristic (ROC) analysis was also performed for each cut-off score. The Youden index seeks to identify the point on the ROC curve that maximizes the equation “J = sensitivity + specificity - 1.” A test with perfect sensitivity and specificity has a Youden index of 1, and, therefore, a screening test’s cut-off score with the highest Youden index optimally balances sensitivity and specificity.[43] Multivariate logistic regression, controlling for age, sex, and race, was performed to determine the odds ratio (OR) for LVO. An upper limit cut-off of last known well time of 270 minutes was applied for analyses involving revascularization, because IV tPA was not routinely given to AIS patients with symptom onset greater than 270 minutes at the study hospital. The false positive rate was defined as 100 × number of false positive / (number of false positive + number of true negatives).

Cohen's kappa was calculated to determine inter-rater reliability for CPSS abstraction with a Cohen's kappa ≥ 0.75 considered "excellent" interrater agreement.[44] STATA 12.1 (StataCorp, College Station, TX) was used for statistical analysis.

Human Subjects Committee Review

Northwestern University's Institutional Review Board (IRB) approved the study, and the need for written informed consent was waived by the IRB (STU00065136).

Results

Characteristics of Study Subjects

A total of 144 patients were initially identified as AIS patients arriving via EMS during the study period, and 138 (95.8%) had CPSS scores that were able to be abstracted from the EMS record and were included in analysis. The median age of patients was 69 (IQR 58–81) years, and 50.7% were male. Overall, 80.4% of patients had a last known well time of 270 minutes or less. A total of 29 patients (21.0%) underwent revascularization, all with IV tPA alone. Of the 29 patients who received IV tPA, 12 (41.4%) did not have an LVO on subsequent vessel imaging and 1 (3.5%) did not have any vessel imaging. The CPSS was ≥2 in 37.7% of patients (Table 1). Stroke or transient ischemic attack was specifically documented as the paramedic impression in 42.0% of cases. Cohen's kappa for CPSS abstraction was 0.80, consistent with excellent interrater reliability.

Main Results

Vessel imaging was performed in 135 patients (97.8%), with a median time to first vessel imaging of 5.9 (IQR 3.6–10.2) hours from ED arrival (Table 1). Overall, 43.7% of patients were found to have an LVO. Patients presenting within 270 minutes of symptom onset with LVO were more likely to receive reperfusion therapy compared to those without LVO (36.4% vs. 18.5%, p=0.036).

The optimal CPSS score to predict LVO was 3, with a Youden index of 0.29, a sensitivity of 0.41, and a specificity of 0.88 (Table 2). The unadjusted OR for the presence of LVO for patients with CPSS=3 was 5.1 (95% CI 2.1–12.2). Adjusting for age, sex, and race, the OR for LVO with CPSS=3 was 5.7 (95% CI 2.3–14.1). Among patients with CPSS=3, 72.7% had a LVO, compared with 34.3% of patients with CPSS ≤2 (p<0.0001). The false positive rate was 11.8%.

The overall median initial NIHSS score was 4 (IQR 1–9). The median NIHSS score was 3 (IQR 1–5) for patients with CPSS ≤2 and 9.5 (IQR 7–16) for patients with CPSS=3 (p<0.0001). Of patients with CPSS=3, 50.0% had NIHSS ≥10 and 26.5% had NIHSS ≥15. The sensitivity and specificity of CPSS=3 for NIHSS ≥10 was 0.57 and 0.84, respectively, and 0.45 and 0.79, respectively, for NIHSS ≥15. The correlation between CPSS and NIHSS score was strong, with Spearman's rho = 0.56 (p<0.0001).

The optimal CPSS cut-off score to predict reperfusion therapy was 2 among patients who arrived with a last known well time of ≤270 minutes. The Youden index was 0.48, with a sensitivity of 0.76 and a specificity of 0.72. The unadjusted OR for reperfusion therapy in patients with CPSS ≥2 and last known well time of ≤270 minutes was 13.0 (95% CI 4.7–35.6). Adjusting for age, sex, and race, the OR for reperfusion therapy in patients with CPSS ≥2 and last known well time of ≤270 minutes was 13.3 (95% CI 4.7–37.5). The unadjusted OR for reperfusion therapy in patients with CPSS=3 and last known well time of ≤270 minutes was 13.1 (95% CI 4.6–37.0). Adjusting for age, sex, and race, the OR for reperfusion therapy in patients with CPSS =3 and last known well time of ≤270 minutes was 15.7 (95% CI 5.0–49.5).

Discussion

In this retrospective review of confirmed consecutive AIS patients at a high-volume, urban stroke center in an EMS system with a single municipal EMS provider agency, we found that a CPSS cut-off score of 3 strongly predicts LVO. This study also suggests that the CPSS, an easy and widely used prehospital stroke screening tool, performs similarly to more complex stroke severity scales, which range in sensitivity between 0.5–0.64 and specificity between 0.83–0.92.[11,23]

Optimizing the treatment of AIS patients in a stroke system of care involves layperson recognition of AIS symptoms, EMS detection of stroke, rapid transport to the most appropriate hospital, efficient ED evaluation, and timely initiation of reperfusion therapy.[19] In an idealized stroke system of care, direct transport by EMS of AIS patients with LVO the CSCs that perform EVT would contribute to timely administration of reperfusion therapy for eligible AIS patients with LVO without delaying IV tPA for AIS patients without LVO. However, in the absence of an idealized stroke system of care with a perfectly performing prehospital LVO screen, balancing sensitivity and specificity of prehospital LVO screening tools is critically important. Prehospital over-triage to a more distant CSC has negative impacts, including potential delays in IV tPA administration for patients without LVO, longer ambulance transport times, longer ambulance out-of-service times, increased transport of stroke mimics, and decreased patient volume at PSCs.[31,45] Under-triage results in patients who would otherwise be eligible for EVT being transported to non-CSC hospitals without EVT capability and, therefore, require an inter-facility transfer, a process known to be associated with delay to EVT, decreased likelihood of receiving EVT, and worse outcomes.[32,33]

Several research groups have developed prehospital stroke severity and LVO screening tools.[11,15,20–30] However, most current prehospital LVO scales require EMS providers to perform a physical examination that requires formal EMS provider training. Furthermore, the prehospital assessment of complex elements such as aphasia, gaze direction, and neglect may introduce errors and delays. Among LVO scales that have been validated in the prehospital setting, the Cincinnati Stroke Triage Assessment Tool involves paramedic assessment of eye gaze deviation, inability to follow commands, and arm drift; this tool was found to have a sensitivity of 71% and specificity of 70% for LVO, without additional paramedic training.[21,24] The Los Angeles Motor Scale (LAMS) involves assessment of facial droop, arm drift, and grip strength, each graded from 0–2, and has a high correlation with NIHSS score at ED arrival.[25,29] The LAMS can achieve a sensitivity of 81% and a specificity of 89% for LVO. The Rapid Arterial Occlusion Evaluation (RACE) has a sensitivity of 85% and specificity of 68% if the RACE score is ≥ 5, but prospective validation studies involved significant paramedic education on correct application of the tool.[26,30]

An advantage of the CPSS is the ease with which EMS providers can be taught to reliably apply the scale.[35] Simple, high-performing screening tools like the CPSS with a cut-off for LVO may strike a favorable balance among sensitivity, specificity, reproducibility, educational costs, and implementation time. For example, for EMS systems that currently use the CPSS as an AIS screen, modifying protocols to use a cut-off of 3 to identify patients with LVO could be easily implemented with minimal additional education for EMS providers.

This study is limited to patients treated at a single stroke center, though the study site is a high-volume stroke center located in a large urban area. Patients were treated prior to publication of the clinical trial results demonstrating benefit of EVT for confirmed LVO.[46] While most patients underwent vessel imaging at some point during their ED and hospital stay, imaging was routinely performed only after IV tPA was administered, most often hours after their ED arrival. A prior study observed that one-third of LVOs recanalize within 44 minutes after IV tPA administration,[47] suggesting that some patients with negative vessel imaging studies in our analysis may have been positive for LVO had the patient had been imaged prior to IV tPA administration. However, this observation biases our results toward the null because it decreases the observed effect size, as patients with LVO tend to have more severe stroke syndromes and higher NIHSS.[38] Additionally, while the decision for reperfusion therapy may be institution-specific, identification of LVO is generalizable across stroke systems of care. This study also only investigated patients with AIS, rather than also including patients with hemorrhagic strokes, a population that also benefits from care at a CSC. However, hemorrhagic stroke constitutes approximately 15% of all strokes, and the benefit of direct EMS transport of hemorrhagic strokes is yet unproven.[48] Identification of hemorrhagic stroke can be an important focus of future research. Since the prehospital protocol at the time of the study employed the CPSS as a stroke screen, as opposed to a stroke severity screen, it is possible that once paramedics obtained one abnormal element of the CPSS, the remainder of the CPSS may not have been performed or may not have been performed with high fidelity. Similarly, dense aphasia and hemi-neglect may limit paramedic assessment of other elements of the CPSS and result in a falsely low CPSS.

Future prospective studies are needed to test the generalizability of using a CPSS cut-off score of 3 for prehospital identification of stroke patients with LVO and the application of this CPSS cut-off score in other EMS systems. Applying CPSS cut-off scores may provide a simple way of screening for AIS patients in EMS protocols that directly transport patients with suspected LVO to CSCs.

Conclusions

The CPSS performs well as a prehospital screen for LVO. The CPSS may be a feasible option as an LVO screen in EMS protocols that direct suspected LVO patients to CSC, particularly because the CPSS is easily adopted by many EMS providers, but further research is needed to validate prospectively the use of the CPSS as a prehospital LVO screen.

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Table 1:

Characteristics of Patients with Vessel Imaging By Presence of Large Vessel Occlusion.

Characteristic		No LVO (n=76)	LVO (n=59)	p-value
Age	(mean years ± SD)	68.3 ± 15.9	68.5 ± 15.1	0.93
Female Sex	n (%)	34 (44.7)	31 (52.5)	0.37
Race	n (%)			
White		44 (57.9)	32 (54.3)	0.67
African American		26 (34.2)	20 (33.9)	0.97
Hispanic		2 (2.6)	3 (5.1)	0.45
Asian		1 (1.3)	2 (3.4)	0.42
Other		3 (4.0)	2 (3.4)	0.87
Last Known Well Time ≤270 minutes	n (%)	65 (85.5)	44 (74.6)	0.11
NIHSS Score	median (IQR)	3 (1–5)	8 (2–17)	<0.0001
Prehospital CPSS	n (%)			
0		31 (40.8)	15 (25.4)	0.06
1		25 (32.9)	13 (22.0)	0.16
2		11 (14.5)	7 (11.9)	0.66
3		9 (11.8)	24 (40.7)	<0.0001
Vessel Imaging Modality	n (%)			
MR Angiography		61 (80.3)	55 (93.2)	0.03
CT Angiography		20 (26.3)	26 (44.1)	0.03
US Doppler		5 (6.6)	2 (3.4)	0.41
Convention Angiography		2 (2.6)	3 (5.1)	0.45
Time to Vessel Imaging	minutes (IQR)	360.4 (222.8–639.0)	327.2 (209.2–521.0)	0.42

LVO: Large Vessel Occlusion; NIHSS: National Institute of Health Stroke Scale; IQR: Inter-Quartile Range; CPSS: Cincinnati Prehospital Stroke Scale; MR: Magnetic Resonance; CT: Computed Tomography; US: Ultrasound.

Table 2:

Performance of Prehospital CPSS Stratified by Cut-off Score in Predicting Large Vessel Occlusion and Reperfusion Therapy.

CPSS cut-off score	Sensitivity	Specificity	Positive Likelihood Ratio	Negative Likelihood Ratio	ROC (Standard Error)
LVO					
CPSS ≥ 1	0.75	0.41	1.26	0.62	0.58 (0.040)
CPSS ≥ 2	0.53	0.74	2.0	0.64	0.63 (0.042)
CPSS = 3	0.41	0.88	3.44	0.67	0.64 (0.037)
Reperfusion Therapy					
CPSS ≥ 1	0.97	0.42	1.67	0.08	0.69 (0.029)
CPSS ≥ 2	0.76	0.72	2.76	0.33	0.74 (0.046)
CPSS = 3	0.59	0.84	3.76	0.49	0.72 (0.050)

CPSS: Cincinnati Prehospital Stroke Scale; LVO: Large Vessel Occlusion; ROC: Receiver Operating Characteristic.