Ambulance Clinical Triage for Acute Stroke Treatment
Paramedic Triage Algorithm for Large Vessel Occlusion

Henry Zhao, MBBS; Lauren Pesavento, BN; Skye Coote, MN; Edrich Rodrigues, MB, ChB; Patrick Salvaris, MBBS; Karen Smith, PhD; Stephen Bernard, MD; Michael Stephenson, BHlthSc; Leonid Churilov, PhD; Nawaf Yassi, PhD; Stephen M. Davis, MD; Bruce C.V. Campbell, PhD

Background and Purpose—Clinical triage scales for prehospital recognition of large vessel occlusion (LVO) are limited by low specificity when applied by paramedics. We created the 3-step ambulance clinical triage for acute stroke treatment (ACT-FAST) as the first algorithmic LVO identification tool, designed to improve specificity by recognizing only severe clinical syndromes and optimizing paramedic usability and reliability.

Methods—The ACT-FAST algorithm consists of (1) unilateral arm drift to stretcher <10 seconds, (2) severe language deficit (if right arm is weak) or gaze deviation/hemineglect assessed by simple shoulder tap test (if left arm is weak), and (3) eligibility and stroke mimic screen. ACT-FAST examination steps were retrospectively validated, and then prospectively validated by paramedics transporting culturally and linguistically diverse patients with suspected stroke in the emergency department, for the identification of internal carotid or proximal middle cerebral artery occlusion. The diagnostic performance of the full ACT-FAST algorithm was then validated for patients accepted for thrombectomy.

Results—In retrospective (n=565) and prospective paramedic (n=104) validation, ACT-FAST displayed higher overall accuracy and specificity, when compared with existing LVO triage scales. Agreement of ACT-FAST between paramedics and doctors was excellent (κ=0.91; 95% confidence interval, 0.79–1.0). The full ACT-FAST algorithm (n=60) assessed by paramedics showed high overall accuracy (91.7%), sensitivity (85.7%), specificity (93.5%), and positive predictive value (80%) for recognition of endovascular-eligible LVO.

Conclusions—The 3-step ACT-FAST algorithm shows higher specificity and reliability than existing scales for clinical LVO recognition, despite requiring just 2 examination steps. The inclusion of an eligibility step allowed recognition of endovascular-eligible patients with high accuracy. Using a sequential algorithmic approach eliminates scoring confusion and reduces assessment time. Future studies will test whether field application of ACT-FAST by paramedics to bypass suspected patients with LVO directly to endovascular-capable centers can reduce delays to endovascular thrombectomy. **(*Stroke*. 2018;49:945-951. DOI: 10.1161/STROKEAHA.117.019307.)**

Key Words: ambulance diversion ■ diagnosis ■ humans ■ stroke ■ triage

Downloaded from http://ahajournals.org by on October 22, 2018

The geographical distribution of endovascular-capable stroke centers necessitates interhospital transfer of patients to receive endovascular thrombectomy. This secondary transfer (drip and ship) is recognized as a source of excessive time delay. A meta-analysis of endovascular trials demonstrated that symptom onset to emergency department arrival was, on average, 142 minutes longer for patients requiring interhospital transfer,[1] which dwarfs all other time delays in the lead-up to the commencement of endovascular therapy. In contemporary clinical practice in Melbourne, Australia, the median time elapsed between initial hospital arrival and endovascular-capable hospital arrival is 128 minutes, despite the travel time between hospitals being ≈20 minutes.[2] Multiple observational studies have now associated this transfer delay with worse patient outcomes.[3,4]

Some regions have implemented prehospital bypass of suspected patients with large vessel occlusion (LVO) using clinical scales, such as the Rapid Arterial Occlusion Evaluation (RACE),[5] Los Angeles Motor Scale (LAMS),[6] Field Assessment Stroke Triage for Emergency Destination (FAST-ED),[7] Cincinnati Stroke Triage Assessment Tool,[8] and Prehospital Acute Stroke Severity Scale.[9] This approach remains unproven, and clinical identification of LVO is imperfect.[10,11] Misclassification errors can result in

Received October 27, 2017; final revision received January 18, 2018; accepted February 5, 2018.

From the Melbourne Brain Centre and Department of Neurology, Royal Melbourne Hospital, Australia (H.Z., L.P., S.C., E.R., P.S., N.Y., S.M.D., B.C.V.C.); Ambulance Victoria, Melbourne, Australia (K.S., S.B., M.S.); The Florey Institute of Neuroscience and Mental Health, University of Melbourne, Australia (L.C., N.Y.); Department of Epidemiology and Preventive Medicine, and Department of Community Emergency Health and Paramedic Practice, Monash University, Australia (K.S., M.S.); and Discipline of Emergency Medicine, University of Western Australia, Australia (K.S., S.B.).

Guest Editor for this article was Markku Kaste, MD, PhD.

The online-only Data Supplement is available with this article at http://stroke.ahajournals.org/lookup/suppl/doi:10.1161/STROKEAHA.117.019307/-/DC1.

Correspondence to Henry Zhao, MBBS, Melbourne Brain Centre, Royal Melbourne Hospital, Grattan St, Parkville, Victoria 3050, Australia. E-mail zhaohdr@live.com

© 2018 American Heart Association, Inc.

patients without LVO bypassing the nearest primary stroke center, thereby potentially delaying thrombolysis or overburdening the endovascular center with non–endovascular-eligible patients. Our group previously studied LVO scale misclassification errors and concluded that bypass may be beneficial, provided emergency medical service (EMS) assessment was reliable and accurate.[12]

EMS accuracy remains an obstacle for current LVO triage scales, with low specificity and positive predictive values (PPVs) when scales are assessed in the field. Only the RACE,[5,13] LAMS,[14,15] and Cincinnati Stroke Triage Assessment Tool[16] have published EMS validation studies, and all have reported specificities of ≤70% for recognition of LVO using vessel imaging as reference standard. With an estimated prehospital LVO prevalence of 15%,[12] PPVs would be 32%, 16%, and 26% for the 3 scales, respectively. As such, when applied to the broad range of suspected patients with stroke in the field, the proportion of true-positive patients is concerningly low. This may be due in part to our previously noted concerns about the reliability of examination items when assessed by EMS, particularly those that are subjective (eg, mild facial palsy and hand grip), subject to confounding (eg, leg weakness because of hip osteoarthritis), difficult to examine in linguistically diverse patients, or are difficult to teach to EMS (eg, National Institutes of Health Stroke Scale[17] [NIHSS] method of extinction assessment[18]). Additionally, current scales do not contain a screening tool to determine endovascular eligibility and exclude stroke mimics.

We, therefore, aimed to design a simple, high-specificity LVO recognition tool that contained items that paramedics could score reliably. The tool would use a sequential algorithmic approach to reduce assessment time for the majority of patients who do not have LVO. We then performed a retrospective and prospective validation of paramedic reliability using the new LVO identification algorithm.

Methods

Algorithm Design and Validation

The data that support the findings of this study are available from the corresponding author on reasonable request. The ambulance clinical triage for acute stroke treatment (ACT-FAST) algorithm was designed in several phases, starting with exploration of clinical deficits with a high predictive value for LVO using the Royal Melbourne Hospital stroke database (Figure I in the online-only Data Supplement). The reference standard for diagnostic accuracy was LVO defined as occlusion of the intracranial internal carotid artery or proximal (M1 segment) middle cerebral artery on the baseline computed tomographic angiogram with NIHSS ≥6, in accordance with American Heart Association class 1 recommendations for endovascular thrombectomy.[19] Using additional data from retrospective and prospective validation datasets, we performed classification and regression tree (CART) analysis using NIHSS subitems as dependent variables to achieve an optimal model for LVO prediction. CART analysis is a recursive partitioning method that splits a large sample in a stepwise fashion into binary subsamples to maximize homogeneity within and separation between the resultant subsamples.[20] The model used a 10-fold internal cross-validation, where data are repeatedly, randomly divided into 10 groups with 9 used to build the model (training) and 1 used to validate (testing), to maximize the area under the receiver operating characteristic curve (AUC). NIHSS subitems were excluded from the model if they were not universally assessable, showed poor reliability when assessed by paramedics, or could not be adequately assessed in uncooperative patients. Analysis was performed using SPM, version 8.2 (Salford Systems, San Diego). The results of CART analysis were then used to select ACT-FAST examination steps, and the partial algorithm was revalidated using retrospective and prospective datasets before the addition of an eligibility and stroke mimic screen step to complete the algorithm.

The full ACT-FAST algorithm subsequently underwent a final validation phase, where paramedics were asked to assess only ACT-FAST using a paper form (Figure I in the online-only Data Supplement) with all necessary instructions and without further input from investigators. The reference standard for diagnostic accuracy in this phase was patients with LVO (using American Heart Association [AHA] class 1 criteria) who were accepted for endovascular thrombectomy at Royal Melbourne Hospital. All study protocols received approval by the institutional human research ethics committee with waiver provided for written patient consent.

Validation Datasets

The retrospective validation dataset consisted of a previously published[12] registry of consecutive paramedic-initiated code strokes at 2 major stroke centers in Melbourne, Australia. The diagnostic performance of ACT-FAST examination steps was compared with existing LVO triage scales derived from baseline NIHSS and hand grip data.

Prospective validation was conducted with Ambulance Victoria paramedics over a 10-month period in the Royal Melbourne Hospital Emergency Department. Ambulance Victoria is a publicly funded ambulance service that is the sole provider of emergency ambulance services for the state of Victoria, which includes Melbourne. All Ambulance Victoria paramedics are trained in advanced life support and use the Melbourne Ambulance Stroke Screen[21] (assessing facial palsy, hand grip, speech, and stroke mimic screen) for routine examination of suspected patients with stroke. Paramedics transporting both suspected patients with stroke to the emergency department and interhospital endovascular transfers were included to increase confidence in sensitivity. Paramedics were asked to complete a paper survey with a schedule of assessments in the emergency department that allowed derivation of the eventual ACT-FAST examination steps, RACE, LAMS, and FAST-ED for each patient (items are shown in Table I in the online-only Data Supplement). The same assessments were completed contemporaneously by a stroke physician allowing assessment of interrater reliability to aid selection of items for the final algorithm. Where assessments were beyond the routine examination performed by paramedics, verbal instruction on performing the assessment and theoretical interpretation from an investigator was given to paramedics to complete the additional assessments, with care taken to ensure paramedics were not biased by the hospital stroke team. To address uncertainties in scoring current LVO scales and to increase reliability, (1) only unilateral limb weakness was scored (if there was weakness of bilateral upper or lower limbs, paramedics were instructed to score weakness as absent); (2) for comparison of reliability, paramedics were instructed to only score weakness if the limb drifted to the stretcher within 10 seconds for arm or 5 seconds for leg (equivalent to NIHSS limb motor subitem ≥2); and 3) hemineglect was assessed using RACE items (hand clapping and recognition of weak arm) and by a global assessment.

Finalized ACT-FAST Algorithm

The finalized ACT-FAST algorithm (Figure) was designed with 2 examination steps, followed by a final eligibility and stroke mimic screen step. The first step of ACT-FAST assesses for unilateral arm weakness using the NIHSS method of arm drift and is fulfilled when 1 arm drifts to the stretcher in <10 seconds. The tool provides additional advice on interpretation in difficult situations, such as patients who are uncooperative. The second step of ACT-FAST depends on which arm is weak. If the right arm is weak, EMS are instructed to look for a severe language disturbance. If the left arm is weak, EMS are instructed to assess for consistent and obvious gaze deviation of both eyes away from the side of weakness. If present, this step is fulfilled, otherwise the EMS is instructed to assess for severe hemineglect by tapping the patient twice on the shoulder and calling their

Downloaded from http://ahajournals.org by on October 22, 2018

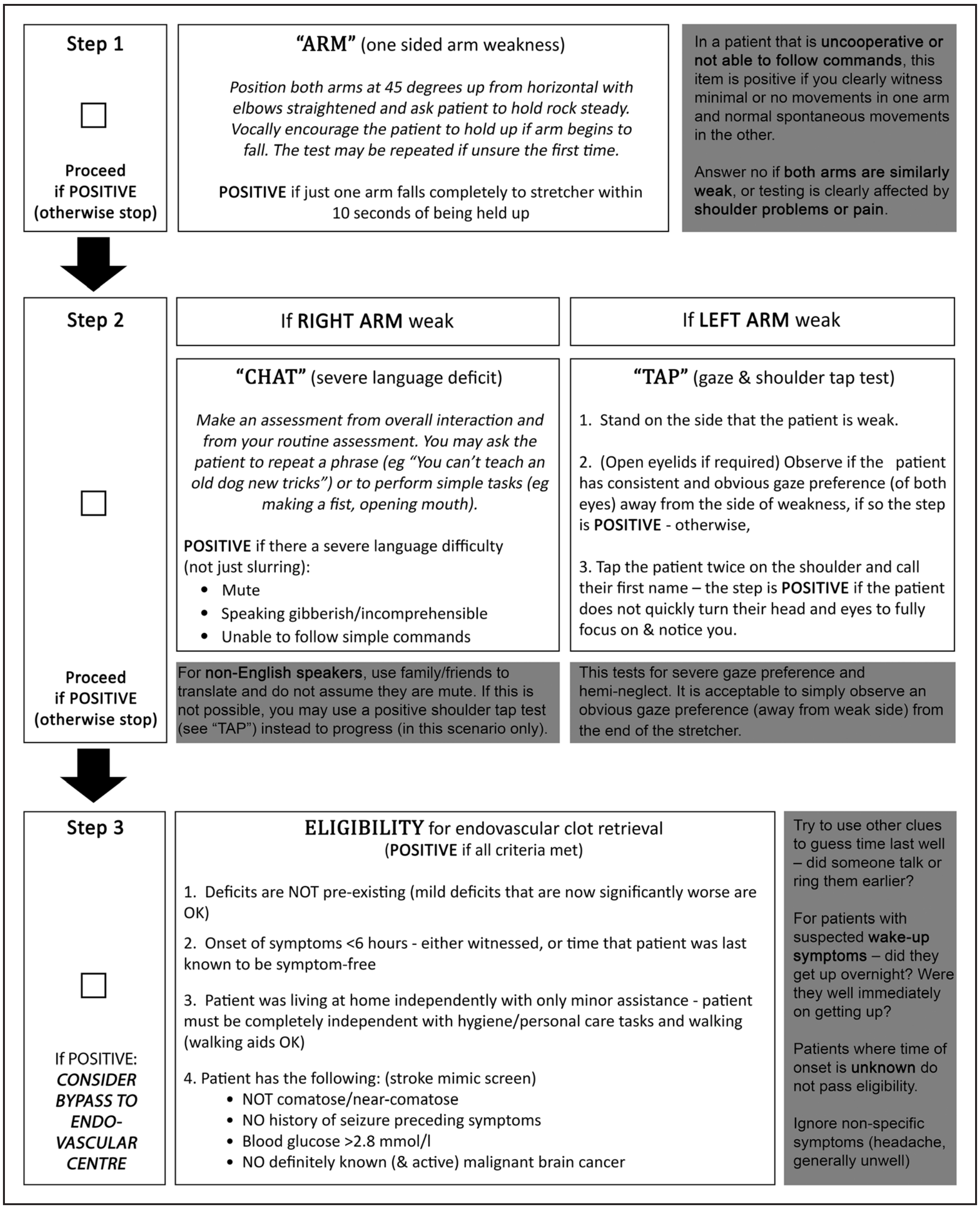

Figure. Ambulance clinical triage for acute stroke treatment algorithm.

first name. If the patient does not quickly turn their head and eyes to focus on the assessor in response to this shoulder tap test, they are assessed as having severe hemineglect. This test was chosen in preference to the NIHSS method of extinction assessment, which paramedics reported to be difficult to assess in uncooperative patients. The last step of ACT-FAST is designed to determine that deficits are not preexisting, that time of onset is <6 hours, to determine premorbid functional level, and to rule out common stroke mimics.

Statistical Analyses

Statistical analyses were conducted with routine parameters, including overall accuracy, sensitivity, specificity, PPV, negative predictive value, AUC, and agreement with vessel imaging using Cohen κ statistic. AUCs for the differing scales were compared using the χ^2 test. Interrater reliability between paramedics and stroke physicians was also analyzed using Cohen κ. κ agreement was interpreted as <0.40, poor; 0.40 to 0.60, fair; 0.60 to 0.80, moderate; and 0.80 to 1.0, excellent.[22] Sample size for prospective validation cohort was estimated at n=102 participants to provide 80% power to detect a κ=0.80 compared with a 2-tailed null hypothesis of κ=0.40 assuming a prevalence of 10%.[22]

Results

Algorithm Design

The results of the paramedic reliability study showed the highest agreement for limb drift, severe language deficit, and gaze deviation, whereas agreement was the lowest for facial palsy and hand grip (Table I in the online-only Data Supplement). Items with poor reliability were, therefore, subsequently excluded from CART analysis. The final decision tree model created using CART analysis for prediction of LVO showed AUC=0.91 for both training and testing samples, with the 3 most important splits being NIHSS motor arm ≥2, combined NIHSS best gaze ≥1 and NIHSS neglect >1, and NIHSS best language ≥2 (Figure II in the online-only Data Supplement).

Downloaded from http://ahajournals.org by on October 22, 2018

Table 1. Retrospective Validation of LVO Identification Tools

	Accuracy	κ	Sensitivity	Specificity	PPV	NPV	AUC
Overall (n=565)							
ACT-FAST examination steps	92.4	0.61 (0.51–0.71)	85.1	93.1	52.6	98.6	0.90
RACE ≥5	88.9	0.52 (0.43–0.62)	91.5	88.6	42.2	99.1	0.90
LAMS ≥4	85.7	0.46 (0.36–0.55)	93.6	84.9	36.1	99.3	0.89
FAST-ED ≥4	87.1	0.49 (0.40–0.59)	95.7	86.3	38.8	99.6	0.91
PASS ≥2	83.4	0.42 (0.33–0.51)	95.7	82.2	32.9	99.5	0.89
C-STAT ≥2	85.3	0.42 (0.33–0.52)	85.1	85.3	34.5	98.4	0.85
Excluding ICH (n=506)							
ACT-FAST examination steps	95.1	0.74 (0.64–0.83)	85.1	96.1	69.0	98.4	0.92
RACE ≥5	93.9	0.70 (0.60–0.80)	91.5	94.1	61.4	99.1	0.93
LAMS ≥4	92.1	0.65 (0.55–0.75)	93.6	91.9	54.3	99.3	0.93
FAST-ED ≥4	92.5	0.66 (0.57–0.76)	95.7	92.2	55.6	99.5	0.94
PASS ≥2	88.5	0.55 (0.45–0.65)	95.7	87.8	44.6	99.5	0.92
C-STAT ≥2	90.3	0.57 (0.46–0.67)	85.1	90.9	48.8	98.4	0.88

Prevalence, 8.9%. LVO defined as internal carotid artery/M1-middle cerebral artery occlusion on CT angiography with NIHSS ≥6. ACT-FAST indicates ambulance clinical triage for acute stroke treatment; AUC, area under the receiver operating characteristic curve; C-STAT, Cincinnati Stroke Triage Assessment Tool; CT, computed tomography; FAST-ED, Field Assessment Stroke Triage for Emergency Destination; LAMS, Los Angeles Motor Scale; LVO, large vessel occlusion; NIHSS, National Institutes of Health Stroke Scale; NPV, negative predictive value; PASS, Prehospital Acute Stroke Severity; PPV, positive predictive value; and RACE, Rapid Arterial Occlusion Evaluation Scale.

Downloaded from http://ahajournals.org by on October 22, 2018

Variations of the 3 examination items were then tested for optimal balance of sensitivity and specificity, with the optimal result comprising the 2 final ACT-FAST examination steps (Table II in the online-only Data Supplement). This was subsequently validated against retrospective and prospective datasets.

Validation of ACT-FAST Examination Steps

ACT-FAST examination steps were retrospectively validated (Table 1) in 565 consecutive paramedic-initiated code strokes (LVO prevalence, 8.3% using AHA criteria) in metropolitan Melbourne, Australia. Demographics for this dataset have been published previously.[12] Statistical comparison of AUC between tools did not show a significant difference (*P*=0.25). However, ACT-FAST showed higher accuracy, specificity, and PPV but lower sensitivity and negative predictive value compared with existing LVO triage scales. These trends were maintained if patients with intracerebral hemorrhage (ICH) were excluded.

For prospective paramedic validation of ACT-FAST examination steps, data were available for a total of 104 patients, after exclusion of 4 because of preexisting deficits. A total of n=93 accompanying paramedic crews from >50 different sites in metropolitan and rural Melbourne participated in the study. Patients were 49.1% male with a mean age of 69 years (range, 21–93) and median NIHSS of 5 (interquartile range, 1–16). A third of patients did not speak English as their first language, and of those, two thirds could not hold a simple conversation in English before the stroke. Breakdown of final patient diagnoses was as follows: LVO fulfilling AHA class 1 criteria n=14 (13.5%; interhospital transfer n=8), LVO not fulfilling criteria because of NIHSS <6 n=2 (1.9%; interhospital transfer n=1), non-LVO ischemic stroke n=40 (38.5%; interhospital transfer n=6), transient ischemic attack n=1 (0.9%), ICH n=11 (10.6%), and stroke mimics n=36 (34.6%). Table 2 shows comparative diagnostic performance of ACT-FAST examination steps against previously published LVO triage scales when assessed by paramedics. ACT-FAST showed superior trends across all parameters compared with RACE, LAMS, and FAST-ED, with the difference more pronounced if ICH was excluded. Sensitivity analysis was tested for robustness, with ACT-FAST negative predictive value maintained >0.95 from prevalence of 5% to 25%. ACT-FAST AUC was significantly higher than existing scales overall (*P*=0.0012). Comparison with individual scales showed a statistically significant difference with FAST-ED (*P*=0.0004), borderline significant difference with RACE (*P*=0.05), and a trend toward superiority with LAMS (*P*=0.07). Detailed misclassification breakdown is shown in Tables III and IV in the online-only Data Supplement.

Validation of the Full ACT-FAST Algorithm

In the final phase, paramedics assessed the full ACT-FAST algorithm de novo in a separate cohort of 60 patients. Of these, 21 patients were accepted for endovascular thrombectomy with the following indications: LVO fulfilling AHA class 1 criteria n=14 (prevalence, 23.3%; interhospital transfer n=8), proximal M2 occlusion n=2, basilar occlusion n=2, extracranial carotid occlusion/dissection n=2, and intracranial atherosclerosis n=1. Table 3 shows the diagnostic performance of ACT-FAST against a reference standard of LVO fulfilling AHA class 1 criteria, as well as when basilar artery occlusion and all other stroke cases accepted for endovascular thrombectomy were included. ACT-FAST algorithm correctly identified 12 of 14 (85.7%) LVOs and displayed only

Table 2. Prospective Paramedic Validation of LVO Identification Tools

	Accuracy	κ	Sensitivity	Specificity	PPV	NPV	AUC
Overall (n=104)							
ACT-FAST examination steps	89.0	0.66 (0.48–0.84)	100	87.2	56.0	100	0.94
RACE ≥5	81.6	0.48 (0.28–0.67)	92.3	80.0	41.4	98.6	0.86 (*P*=0.05)*
LAMS ≥4	82.4	0.50 (0.31–0.68)	93.9	80.7	43.3	98.6	0.91 (*P*=0.07)*
FAST-ED ≥4	78.0	0.45 (0.28–0.62)	100	74.4	38.9	100	0.88 (*P*=0.0004)*
Excluding ICH (n=93)							
ACT-FAST examination steps	94.4	0.82 (0.66–0.97)	100	93.3	73.7	100	0.97
RACE ≥5	86.4	0.59 (0.39–0.79)	92.3	85.3	52.2	98.5	0.89 (*P*=0.06)*
LAMS ≥4	87.9	0.63 (0.44–0.82)	93.9	87.0	56.5	98.5	0.93 (*P*=0.08)*
FAST-ED ≥4	84.3	0.58 (0.39–0.76)	100	81.3	50.0	100	0.91 (*P*=0.0015)*

Prevalence, 13.5%. LVO defined as internal carotid artery/M1-middle cerebral artery occlusion on CT angiography with NIHSS ≥6. ACT-FAST indicates Ambulance Clinical Triage for Acute Stroke Treatment; AUC, area under the receiver operating characteristic curve; CT, computed tomography; FAST-ED, Field Assessment Stroke Triage for Emergency Destination; LAMS, Los Angeles Motor Scale; LVO, large vessel occlusion; NIHSS, National Institutes of Health Stroke Scale; NPV, negative predictive value; PPV, positive predictive value; and RACE, Rapid Arterial Occlusion Evaluation Scale.

*Comparison with ACT-FAST.

3 false-positive misclassifications in patients who did not fit AHA class 1 criteria (2 proximal M2 occlusions and 1 fully occlusive extracranial dissection). However, all 3 patients still received endovascular thrombectomy at our institution. Sensitivity was lower if basilar artery occlusions and all other stroke cases accepted for endovascular therapy were included, but specificity still remained high. Agreement between paramedics and stroke physicians for assessing patients as algorithm positive or algorithm negative was excellent (κ=0.91; 95% confidence interval, 0.79–1.0).

Discussion

The 3-step ACT-FAST algorithm is the first published algorithmic approach for LVO identification. Despite containing fewer examination steps compared with existing scales, ACT-FAST displayed higher specificity and accuracy for detection of LVO when used by EMS. Although not powered specifically for this purpose, ACT-FAST examination steps showed a statistically significant improvement in diagnostic performance compared with FAST-ED and a trend to superiority compared with RACE and LAMS. ACT-FAST is also the first tool to include an additional history eligibility and stroke mimic screen step, allowing increased accuracy for identification of patients likely to be accepted for endovascular thrombectomy. Furthermore, despite minimal training, paramedics were able to achieve excellent agreement with stroke physician assessment of ACT-FAST examination steps and the full algorithm. Optimal characteristics for a clinical LVO identification tool have been proposed,[11] including ease of use, applicability to unselected populations, high interrater reliability, high accuracy for stroke and LVO, validation in external datasets and prehospital, and proven benefit to patient outcomes. This study fulfills the majority of these criteria and lays the groundwork for assessing benefit of prehospital bypass using ACT-FAST.

ACT-FAST was designed to identify a severe middle cerebral artery syndrome with a focus on improving specificity, without adversely affecting sensitivity. The main false-negative misclassifications, therefore, occur in patients with LVO who present with a milder clinical syndrome. The negative impact of misclassification may be mitigated by the association of milder clinical severity with better collateral blood flow. Time delays may have less adverse impact in these patients.[23] The main false-positive misclassifications with ACT-FAST were in patients with ICH, who are generally clinically indistinguishable from infarcts and can never be fully excluded by clinical means. However, because no time-dependent therapy is currently available for ICH, inadvertent bypass to an endovascular center is not harmful. Indeed, there are potential advantages to managing patients with ICH in comprehensive

Downloaded from http://ahajournals.org by on October 22, 2018

Table 3. Agreement of Ambulance Clinical Triage for Acute Stroke Treatment Algorithm With LVO Accepted for Endovascular Thrombectomy (n=60)

	Accuracy	κ	Sensitivity	Specificity	PPV	NPV
Anterior LVO (AHA class 1*) accepted for EVT; prevalence, 23.3%	91.7	0.77 (0.58–0.96)	85.7	93.5	80.0	95.6
Anterior LVO (AHA class 1*) and basilar artery occlusion accepted for EVT; prevalence, 26.7%	88.3	0.70 (0.49–0.91)	75.0	93.2	80.0	91.1
All stroke cases accepted for EVT; prevalence, 35%	90.0	0.77 (0.59–0.94)	71.4	100	100	86.7

EVT indicates endovascular thrombectomy; LVO, large vessel occlusion; NIHSS, National Institutes of Health Stroke Scale; NPV, negative predictive value; and PPV, positive predictive value.

*Defined as intracranial internal carotid artery/M1-middle cerebral artery occlusion with NIHSS ≥6.

stroke centers because of greater physician experience and the availability of neurosurgical support.

There are several inherent advantages of an algorithm over a traditional scale used in existing triage tools. The first step in the algorithm rapidly excludes the majority of patients in just a few seconds and, therefore, saves considerable assessment time, compared with scales in which all items must be scored before the classification can be determined. When using a scale, EMS must also remember the differential scoring of each subitem and the overall cutoff score, creating potential for scoring errors in a time-pressured environment. Specificity can also be reduced in scale-based tools because odd combinations of deficits can combine to reach the cutoff score, whereas the ACT-FAST algorithm enforces recognition of a highly predictive severe middle cerebral artery syndrome in all patients.

We attempted to make ACT-FAST robust in challenging prehospital environments by giving paramedics extra guidance with uncooperative, aphasic, and non-English speaking patients, and ensuring, as much as possible, examination steps were language neutral and able to be performed in patients with severe deficits. We also avoided subjective items, such as facial palsy and hand grip, where interrater reliability was demonstrably lower. Our gaze and shoulder tap test is a novel assessment that makes paramedic assessment of gaze deviation and severe hemineglect simple, practical, and reliable. In contrast, the NIHSS method of bilateral simultaneous extinction is challenging in patients who are aphasic, non-English speaking, or have visual/sensory deficits. The RACE scale uses clapping and arm recognition to test hemineglect. However, in our study, most patients with a severe syndrome were unable to clap because of severe arm weakness, and arm recognition was also impractical in non-English speaking, anarthric, or aphasic patients. We think our avoidance of these complicating factors underlies the similar accuracy of ACT-FAST in prospective assessment by paramedics versus retrospective assessment by stroke physicians.

The strengths of this study are that we have provided results of retrospective and prospective validation in culturally diverse patients who are representative of the undifferentiated prehospital suspected stroke population of Melbourne, Australia, and many other localities. Of note, one third of the cohort did not speak English as a first language.

The limitations of this study are that the prospective cohort is relatively small and derived from a single endovascular center, although the study involved a large number of assessing paramedic crews, distributed across >50 metropolitan and rural sites. Participants were assessed by paramedics trained in the Melbourne Ambulance Stroke Screen for screening of suspected patients with stroke. The generalizability of our results may, therefore, be affected by differing levels of EMS personnel training worldwide and by the use of alternate screening stroke tools. However, although ACT-FAST was tested subsequent to the Melbourne Ambulance Stroke Screen, patients with negative Melbourne Ambulance Stroke Screen assessment would not pass ACT-FAST step 1. Using ACT-FAST as the initial assessment pre-hospital would, therefore, inflate the specificity (as the rate of true-negatives rises with higher proportion of stroke mimics) with likely little detrimental effect on sensitivity.

Paramedics also assessed deficits in the hospital emergency department rather than in the prehospital environment, which allowed elimination of agreement errors because of symptom fluctuation. However, future research should focus on validation in the prehospital setting and in disparate EMS networks. Paramedics received additional theoretical instructions during the prospective validation of ACT-FAST examination steps, which may represent a source of bias in assessment and in comparison with other scales. However, all tools were subsequently derived from the same common dataset. Paramedics subsequently assessed the full ACT-FAST algorithm without further instruction from investigators.

Potentially, the assessments performed by paramedics and the hospital stroke team were also not truly independent as sources of information were shared. Nonetheless, we took care not to influence paramedic judgment and did not provide any additional assistance if paramedics asked for help with interpretation. In addition, we enriched the proportion of LVO by including patients transferred for endovascular thrombectomy to obtain a more precise estimate of sensitivity. This was a deliberate selection bias that artificially inflated the LVO prevalence and may affect interpretation of the PPV/negative predictive value. We also informed paramedics accompanying transfers that the patient was not necessarily ACT-FAST positive to help reduce assessment bias.

ACT-FAST was not designed to identify endovascular-eligible posterior circulation occlusions. These patients are less common and have a different set of presenting deficits, which would require a separate approach to identification. We also accept that eligibility for endovascular thrombectomy is evolving and likely to extend beyond current AHA guidelines. However, attempting to capture these generally milder strokes with a clinical identification tool would inevitably reduce specificity and PPV, with a resultant unfavorable effect on bypass of non-LVO patients.

Summary

The 3-step ACT-FAST algorithm is a simple, rapid, and reliable tool for the identification of severe anterior circulation strokes likely to be eligible for endovascular thrombectomy. ACT-FAST is the first published algorithmic approach to LVO identification and, when assessed prospectively by paramedics, improved accuracy and specificity compared with existing LVO triage scales. Steps were selected to include only 3 highly reliable examination items and provide practical tips for EMS for unselected, culturally diverse populations. ACT-FAST additionally contains history eligibility criteria that improves accuracy of recognition of endovascular-eligible patients with LVO. The streamlined algorithmic approach has several advantages over a traditional scale and presents a more practical option for implementation in large prehospital EMS networks. Further research will establish accuracy when applied by paramedics in a large geographic region and the benefit of bypassing ACT-FAST–positive patients directly to an endovascular-capable center.

Sources of Funding

H. Zhao received academic funding through the Royal Melbourne Hospital Neurosciences Foundation and Australian Commonwealth Scholarship.

Downloaded from http://ahajournals.org by on October 22, 2018

Dr Campbell is supported by the National Health and Medical Research Council of Australia Career Development Fellowship (GNT1111972) and Heart Foundation Future Leader's Fellowship (100782).

Disclosures

None.

References

1. Saver JL, Goyal M, van der Lugt A, Menon BK, Majoie CB, Dippel DW, et al; HERMES Collaborators. Time to treatment with endovascular thrombectomy and outcomes from ischemic stroke: a meta-analysis. *JAMA*. 2016;316:1279–1288. doi: 10.1001/jama.2016.13647.
2. Ng FC, Low E, Andrew E, Smith K, Campbell BCV, Hand PJ, et al. Deconstruction of interhospital transfer workflow in large vessel occlusion: real-world data in the thrombectomy era. *Stroke*. 2017;48:1976–1979. doi: 10.1161/STROKEAHA.117.017235.
3. Mohamad NF, Hastrup S, Rasmussen M, Andersen MS, Johnsen SP, Andersen G, et al. Bypassing primary stroke centre reduces delay and improves outcomes for patients with large vessel occlusion. *European Stroke Journal*. 2016;1:85–92.
4. Froehler MT, Saver JL, Zaidat OO, Jahan R, Aziz-Sultan MA, Klucznik RP, et al; STRATIS Investigators. Interhospital transfer before thrombectomy is associated with delayed treatment and worse outcome in the STRATIS Registry (Systematic Evaluation of Patients Treated With Neurothrombectomy Devices for Acute Ischemic Stroke). *Circulation*. 2017;136:2311–2321. doi: 10.1161/CIRCULATIONAHA.117.028920.
5. de la Ossa NP, Carrera D, Gorchs M, Querol M, Millan M, Gomis M, et al. Design and validation of a prehospital stroke scale to predict large arterial occlusion the rapid arterial occlusion evaluation scale. *Stroke*. 2014;45:87–91.
6. Nazliel B, Starkman S, Liebeskind DS, Ovbiagele B, Kim D, Sanossian N, et al. A brief prehospital stroke severity scale identifies ischemic stroke patients harboring persisting large arterial occlusions. *Stroke*. 2008;39:2264–2267. doi: 10.1161/STROKEAHA.107.508127.
7. Lima FO, Silva GS, Furie KL, Frankel MR, Lev MH, Camargo ÉC, et al. Field assessment stroke triage for emergency destination: a simple and accurate prehospital scale to detect large vessel occlusion strokes. *Stroke*. 2016;47:1997–2002. doi: 10.1161/STROKEAHA.116.013301.
8. Katz BS, McMullan JT, Sucharew H, Adeoye O, Broderick JP. Design and validation of a prehospital scale to predict stroke severity: Cincinnati prehospital stroke severity scale. *Stroke*. 2015;46:1508–1512. doi: 10.1161/STROKEAHA.115.008804.
9. Hastrup S, Damgaard D, Johnsen SP, Andersen G. Prehospital acute stroke severity scale to predict large artery occlusion: design and comparison with other scales. *Stroke*. 2016;47:1772–1776. doi: 10.1161/STROKEAHA.115.012482.
10. Turc G, Maïer B, Naggara O, Seners P, Isabel C, Tisserand M, et al. Clinical scales do not reliably identify acute ischemic stroke patients with large-artery occlusion. *Stroke*. 2016;47:1466–1472. doi: 10.1161/STROKEAHA.116.013144.
11. Michel P. Prehospital scales for large vessel occlusion: closing in on a moving target. *Stroke*. 2017;48:247–249. doi: 10.1161/STROKEAHA.116.015511.
12. Zhao H, Coote S, Pesavento L, Churilov L, Dewey HM, Davis SM, et al. Large vessel occlusion scales increase delivery to endovascular centers without excessive harm from misclassifications. *Stroke*. 2017;48:568–573. doi: 10.1161/STROKEAHA.116.016056.
13. Perez de la Ossa N, Ribo M, Jimenez X, Abilleira S. Prehospital scales to identify patients with large vessel occlusion. *Stroke*. 2016;47:2877–2878.
14. Noorian A, Sanossian N, Liebeskind DS, Starkman S, Eckstein M, Stratton S, et al. Field validation of prehospital LAMS score to identify large vessel occlusion ischemic stroke patients for direct routing to emergency neuroendovascular centers. *Stroke*. 2016;47:A83–A83.
15. Noorian AR, Sanossian N, Shkirkova K, Liebeskind DS, Eckstein M, Stratton S, et al. Paramedic-administered LAMS identifies ischemic stroke with large vessel occlusion and intracranial hemorrhage for routing to comprehensive stroke centers and compares favorably to other screening methods. 2017;48:A118.
16. McMullan JT, Katz B, Broderick J, Schmit P, Sucharew H, Adeoye O. Prospective prehospital evaluation of the Cincinnati stroke triage assessment tool. *Prehosp Emerg Care*. 2017;21:481–488. doi: 10.1080/10903127.2016.1274349.
17. Lyden P, Raman R, Liu L, Grotta J, Broderick J, Olson S, et al. NIHSS training and certification using a new digital video disk is reliable. *Stroke*. 2005;36:2446–2449. doi: 10.1161/01.STR.0000185725.42768.92.
18. Demeestere J, Garcia-Esperon C, Lin L, Bivard A, Ang T, Smoll NR, et al. Validation of the National Institutes of Health stroke scale-8 to detect large vessel occlusion in ischemic stroke. *J Stroke Cerebrovasc Dis*. 2017;26:1419–1426. doi: 10.1016/j.jstrokecerebrovasdis.2017.03.020.
19. Powers WJ, Derdeyn CP, Biller J, Coffey CS, Hoh BL, Jauch EC, et al; American Heart Association Stroke Council. 2015 American Heart Association/American Stroke Association focused update of the 2013 guidelines for the early management of patients with acute ischemic stroke regarding endovascular treatment: a guideline for healthcare professionals from the American Heart Association/American Stroke Association. *Stroke*. 2015;46:3020–3035. doi: 10.1161/STR.0000000000000074.
20. James G, Witten D, Hastie T, Tibshirani R. *An Introduction to Statistical Learning*. New York, NY: Springer-Verlag; 2013;303.
21. Bray JE, Martin J, Cooper G, Barger B, Bernard S, Bladin C. Paramedic identification of stroke: community validation of the melbourne ambulance stroke screen. *Cerebrovasc Dis*. 2005;20:28–33. doi: 10.1159/000086201.
22. Sim J, Wright CC. The kappa statistic in reliability studies: use, interpretation, and sample size requirements. *Phys Ther*. 2005;85:257–268.
23. Ribo M, Flores A, Rubiera M, Pagola J, Sargento-Freitas J, Rodriguez-Luna D, et al. Extending the time window for endovascular procedures according to collateral pial circulation. *Stroke*. 2011;42:3465–3469. doi: 10.1161/STROKEAHA.111.623827.

Downloaded from http://ahajournals.org by on October 22, 2018