

The FAST-ED App: A Smartphone Platform for the Field Triage of Patients With Stroke

Raul G. Nogueira, MD*; Gisele S. Silva, MD, MPH, PhD*;
Fabricio O. Lima, MD, MPH, PhD; Yu-Chih Yeh, PharmD; Carol Fleming, RN;
Daniel Branco, MD, PhD; Arthur H. Yancey, MD, MPH; Jonathan J. Ratcliff, MD, MPH;
Robert Keith Wages, BS; Earnest Doss; Mehdi Bouslama, MD; Jonathan A. Grossberg, MD;
Diogo C. Haussen, MD; Teppei Sakano, BCS; Michael R. Frankel, MD

Background and Purpose—The Emergency Medical Services field triage to stroke centers has gained considerable complexity with the recent demonstration of clinical benefit of endovascular treatment for acute ischemic stroke. We sought to describe a new smartphone freeware application designed to assist Emergency Medical Services professionals with the field assessment and destination triage of patients with acute ischemic stroke.

Methods—Review of the application's platform and its development as well as the different variables, assessments, algorithms, and assumptions involved.

Results—The FAST-ED (Field Assessment Stroke Triage for Emergency Destination) application is based on a built-in automated decision-making algorithm that relies on (1) a brief series of questions assessing patient's age, anticoagulant usage, time last known normal, motor weakness, gaze deviation, aphasia, and hemineglect; (2) a database of all regional stroke centers according to their capability to provide endovascular treatment; and (3) Global Positioning System technology with real-time traffic information to compute the patient's eligibility for intravenous tissue-type plasminogen activator or endovascular treatment as well as the distances/transportation times to the different neighboring stroke centers in order to assist Emergency Medical Services professionals with the decision about the most suitable destination for any given patient with acute ischemic stroke.

Conclusions—The FAST-ED smartphone application has great potential to improve the triage of patients with acute ischemic stroke, as it seems capable to optimize resources, reduce hospital arrivals times, and maximize the use of both intravenous tissue-type plasminogen activator and endovascular treatment ultimately leading to better clinical outcomes. Future field studies are needed to properly evaluate the impact of this tool in stroke outcomes and resource utilization. (Stroke. 2017;48:00-00. DOI: 10.1161/STROKEAHA.116.016026.)

Key Words: algorithms ■ aphasia ■ emergency medicine ■ stroke ■ triage

Emergency Medical Services (EMS) field triage to stroke centers has gained considerable complexity because the demonstration of clinical benefit of endovascular treatment (ET) in recent randomized clinical trials.¹ As a result, it has become critical to develop objective prehospital triage criteria that appropriately identify patients who are most likely to benefit from services only available at Comprehensive Stroke Centers (CSCs) and therefore require direct transportation, while also facilitating the proper triage of less complex or lower acuity patients to the nearest stroke center (CSCs, Primary Stroke Centers [PSCs], or Acute Stroke Ready Hospitals [ASRHs]). Proper selection of the destination stroke center will enhance appropriate resource use to meet the needs

of individual patients to optimize time to reperfusion and the broader communities by minimizing the time an ambulance is unnecessarily out of service, and will more homogeneously distribute patients with stroke to minimize the effects of crowding on a single healthcare system. Although field identification of potential candidates for mechanical thrombectomy is possible using stroke scales designed to recognize large vessel occlusion strokes (LVOS),²⁻⁶ the decision tree is substantially more complex because many of these patients are also candidates for intravenous thrombolysis (IVT), which could often be more promptly provided at a closer location. Therefore, an optimal destination triage algorithm should not only include the probability of LVOS but also include information about

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Marcus Stroke and Neuroscience Center (R.G.N., C.F., J.J.R., M.B., J.A.G., D.C.H., M.R.F.) and Department of Emergency Medicine (A.H.Y., J.J.R.), Grady Memorial Hospital, Emory University School of Medicine, Atlanta, GA; Department of Neurology, Federal University of São Paulo/UNIFESP and Programa Integrado de Neurologia, Hospital Israelita Albert Einstein, Brazil (G.S.S.); Ciências da Saúde, Curso de Medicina, Universidade de Fortaleza, Brazil (F.O.L.); Allm Group, Tokyo, Japan (Y.-C.Y., T.S.); Medicinia, Sao Paulo, Brazil (D.B.); and Georgia Office of EMS and Trauma, Brookhaven (R.K.W., E.D.).

*Drs Nogueira and Silva contributed equally.

Correspondence to Raul G. Nogueira, MD, 49 Jesse Hill Jr Drive SE, Room 333, Atlanta, GA 30303. E-mail raul.g.nogueira@emory.edu

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the eligibility for IVT and real-time transportation time differences between the closest CSC versus PSC/ASRH.

An ideal platform should permit customization for the needs a particular region, be cost free to the end user, and be broadly and easily available with great portability while offering a user-friendly interface and decision algorithm that decreases cognitive load. Applications designed for smartphones fulfill most of those characteristics. In fact, the use of smartphones has grown substantially among healthcare professionals and already has many different purposes in the area of stroke. Our objective is to report on a new smartphone freeware application designed to assist emergency medical professionals with the field assessment and destination triage of patients with acute stroke. Herein we provide a detailed description of the application and its decision trees as well as the processes around its development and maintenance.

Materials and Methods

Review of the application's platform and its development as well as the different variables, assessments, algorithms, and assumptions involved.

Results

Application Platform and Development

The concept was to formulate a short series of critical clinical questions that in combination with automated data generated by the system would estimate the likelihood of the patient being a candidate for IVT or ET upon arrival at surrounding hospitals (Figures 1 and 2). The application uses Global Positioning System technology to compute the different transportation times between the patient location in the field and all neighboring stroke centers according to PSC/ASRH versus CSC categories. Depending on individual patient characteristics including stroke severity, age, use of anticoagulation, and time last known well (TLKW) as well as transportation times (considering distances and traffic information) and specific center capabilities (PSC/ASRH versus CSC), the application will then direct EMS to the most suitable stroke center for any given case (Figure 2).

The application was developed for iPhone and Android smartphones using commercially available software development toolkits (SDK 3.0, Apple Inc and Android SDK 7.1.1 (API 25), respectively). A server was developed to register the qualifying regional hospitals (ASRH, PSCs, and CSCs) and the questions. The application connects to the server to bring up the clinical questions, compute the answers, and to generate a decision based on stroke severity, treatment eligibility, ambulance location, and real-time traffic information. Academic stroke neurologists led the algorithm development with critical input from community stroke experts, emergency physicians, and EMS personnel. The application development included the pro bono collaboration with two medical software companies: Allm Group, Tokyo, Japan (App final programming and maintenance) and Medicinia, São Paulo, Brazil (initial prototyping for proof of concept). An agreement was executed with all parties involved to provide the App to EMS and other users free of charge. (<https://itunes.apple.com/us/app/fast-ed-triage/>

id1099779970?mt=8; <https://play.google.com/store/apps/details?id=net.allm.fasted>).

Variables, Assessments, Algorithm, and Assumptions

The algorithms for the destination guidelines were based on IVT eligibility, likelihood of LVOS/ET eligibility, and distance/transportation times to PSC/ASRH versus CSC. Variables that define acceptable transportation times, age thresholds for treatment, and regional door-to-needle times may be left in the default settings detailed below or adapted by regional stroke, emergency, and EMS leadership such that it represents their community needs and goals.

IVT Eligibility: Anticoagulation Variable

Ischemic strokes remain significantly more common than hemorrhagic strokes in anticoagulated patients.⁷ Nevertheless, most of the anticoagulated patients are not eligible for IVT. Current guidelines exclude patients on warfarin and international normalized ratio >1.7 who present within 3 hours of stroke onset and those who present between 3 and 4.5 hours regardless their international normalized ratio values. The use of intravenous tissue-type plasminogen activator (tPA) in patients on direct thrombin inhibitors or direct factor Xa inhibitors is not recommended unless laboratory tests, such as aPTT, international normalized ratio, platelet count, ecarin clotting time, thrombin time, or appropriate direct factor Xa activity assays are normal or the patient has not received these agents for >48 hours (assuming normal renal function).⁸ As the aforementioned tests are not typically available in the field and given the overall low likelihood for IVT eligibility in the anticoagulated population, the algorithm reasonably assumes that patients on anticoagulation will be less likely to receive IVT. Therefore, as long as the transportation time difference between the closest CSC and the closest PSC/ASRH is less than the "variable X" (preset at 10 minutes in the default algorithm, but adjustable; Figure 3), patients with moderate to high chance of LVOS (≥30%) are preferentially referred to a CSC. We believe that transportation time differences longer than 10 minutes are not justifiable because these patients are also at higher risk of intracranial hemorrhage potentially requiring emergent reversal of the anticoagulation. However, a small time delay to get to the nearest CSC seems reasonable given that the greater likelihood these patients will have endovascular therapy as their only possible reperfusion strategy. Moreover, in case the patient needs emergent intervention for a hemorrhagic event, neurosurgical back up is, in general, more promptly available at a CSC. This default approach may be modified to suit the needs of a particular region. The "variable X" can be easily set for 0 minutes in which case the anticoagulation issue would then be disregarded.

IVT Eligibility: Age Variable

On the basis of the results of the National Institute of Neurological Disorders and Stroke and ECASS-III trials, and in agreement with the current guidelines, the default algorithm for guiding intravenous tPA treatment uses time windows of 0 to 3 and 0 to 4.5 hours for patients ≤80 and >80 years, respectively.^{8,9} However, considering that the IST-3 trial has demonstrated that the overall reduction in

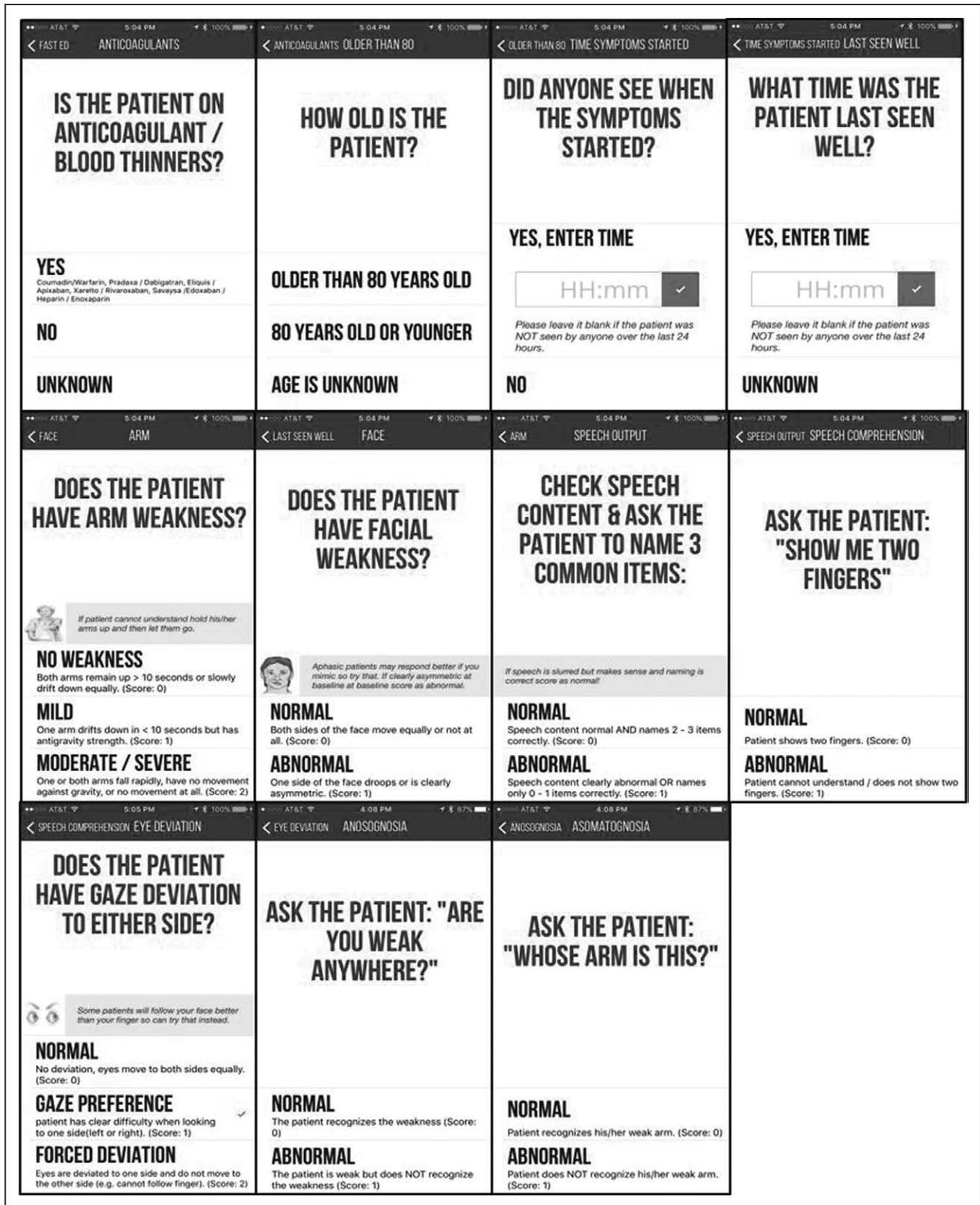


Figure 1. FAST-ED (Field Assessment Stroke Triage for Emergency Destination) App Display: questions. CSC indicates Comprehensive Stroke Centers; IV, intravenous; PSC, Primary Stroke Centers; and tPA, tissue-type plasminogen activator.

disability benefit of IVT does not seem to be diminished in elderly patients treated within 6 hours, many experts defend the extension of the intravenous tPA time window to 4.5

hours regardless of age.¹⁰ If any given region decides to extend the IVT window to 4.5 hours for patients older than 80 years, the “variable A” (IVT window in >80 years) can be

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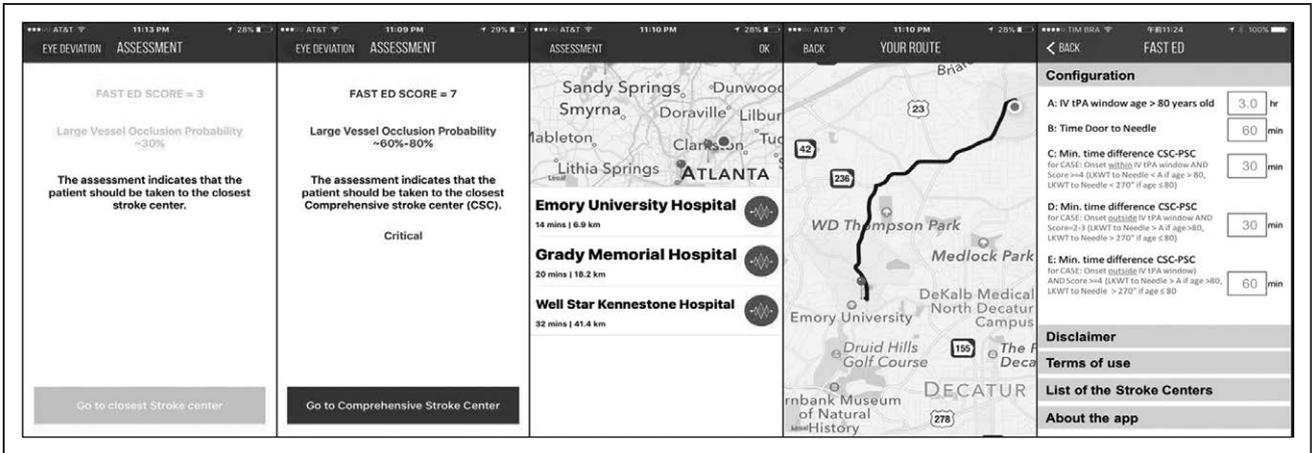


Figure 2. FAST-ED (Field Assessment Stroke Triage for Emergency Destination) App Display: automated output and configurable variables. CSC indicates Comprehensive Stroke Centers; LKWTT, last known well time; and PSC, Primary Stroke Centers.

easily set for 270 minutes in which case the influence of age would then be nullified (Figure 4).

Time Variables

The user enters information about the time of stroke onset (or TLKW if stroke onset is unknown). On the basis of location and traffic information, the App calculates the travel time to

the closest stroke center (“variable B”; Figure 3). The average door-to-needle time for the region (“variable C”, adjustable) is then used to define whether the patient would be a likely candidate for IVT upon arrival at the closest stroke center by applying the following formula: $TLKW + B + C \leq \text{intravenous tPA Window}$.

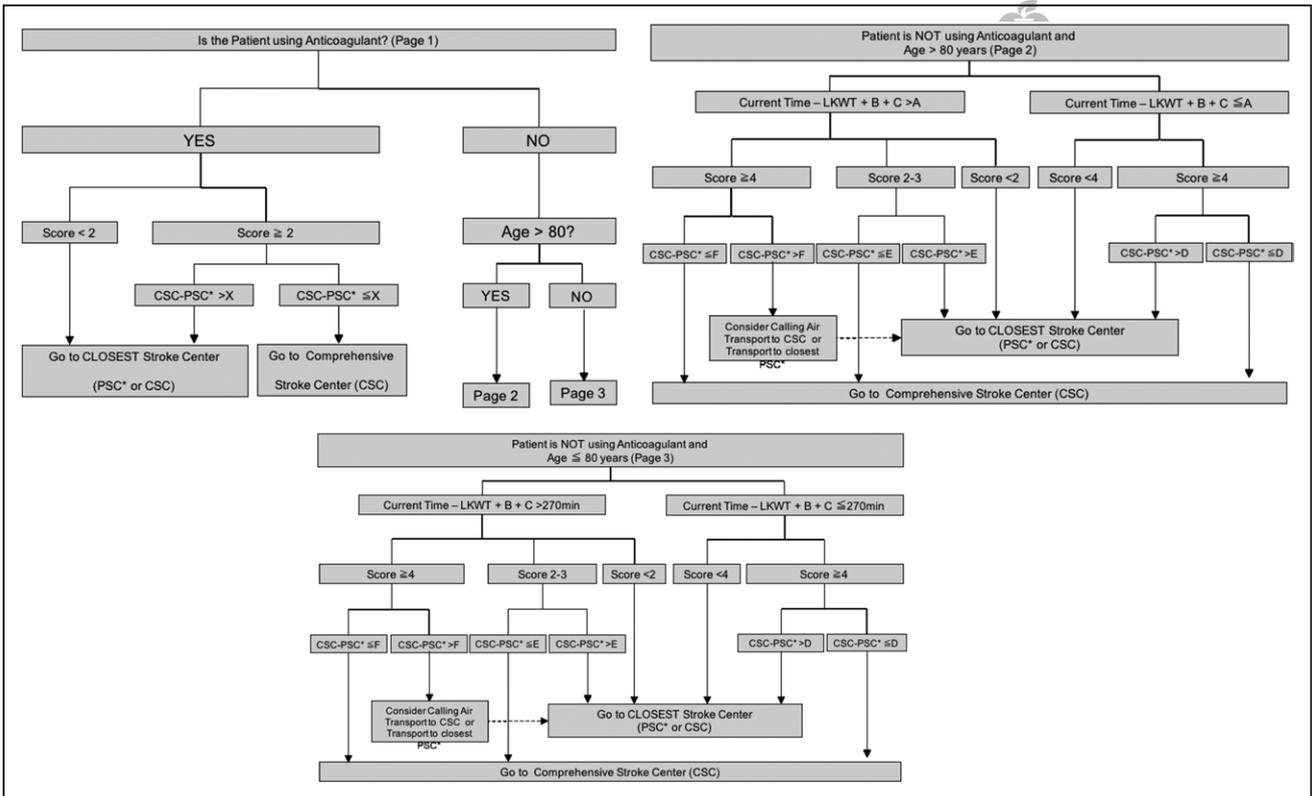


Figure 3. FAST-ED (Field Assessment Stroke Triage for Emergency Destination) decision-making algorithm. *for practical purposes the “PSC” category also includes Acute Stroke Ready Hospitals (ASRHs). MTTD=maximal transportation time difference between the closest Comprehensive Stroke Centers (CSC) and the closest Primary Stroke Centers (PSC)/ASRH; X=MTTD for anticoagulated patients with scores ≥ 2 to be preferentially referred to a CSC; A=intravenous tissue-type plasminogen activator (tPA) window in patients aged >80 years; B=travel time from site to the CSC; C=average regional door-to-needle time; D=MTTD for intravenous tPA eligible patients with scores ≥ 4 to be preferentially referred to a CSC; E=MTTD for intravenous tPA ineligible patients with scores 2 to 3 to be preferentially referred to a CSC; F=MTTD for intravenous tPA ineligible patients with scores ≥ 4 to be preferentially referred to a CSC. *Configurable variables: X is preset at 10 minutes; A is preset at 180 minutes; B is preset at 60 minutes; D and E are preset at 30 minutes, and F is preset at 60 minutes.

LVOS Likelihood Assessment

The FAST-ED (Field Assessment Stroke Triage for Emergency Destination) scale has similar accuracy in the prediction of LVOS as the NIHSS (National Institutes of Health Stroke Scale) but is significantly less time consuming and easier to use (Figure 1).² The scale has a ternary distribution for the overall likelihood of LVOS (0–1, <15%; 2–3, 30%; and ≥ 4 –6, 0%–85%). This should theoretically result in better conformability to different patient scenarios when compared with binary distribution scales.

Assessment, Decision-Making Algorithm, and Default Times

There are 2 essential questions in the destination triage of patients with stroke (Figure 3): (1) by the time the patient arrives to the hospital, what will be his/her treatment options: IVT only, ET only, both IVT and ET, or neither one? (2) Considering these treatment possibilities, how much longer it would take to transport the patient to the closest CSC versus PSC/ASRH? The answer to these questions can be quickly provided by a combination of manually entered and system-generated data. The user answers the questions about: (1) the use of anticoagulation (yes versus no versus unknown; if unknown system assumes no), (2) age (≤ 80 years versus > 80 years versus unknown; if unknown system assumes > 80 years), (3) time of stroke onset or TLKW (if unknown system assumes > 4.5 hours), and (4) FAST-ED scale (Figures 1 and 2). The App automatically assesses the transportation time to the closest PSCs/ASRHs and CSCs. If the patient is not a likely candidate for either IVT or ET, he/she is preferentially referred to the closest stroke center, which will be more likely a PSC/ASRH. If the patient is likely a candidate for IVT only, he/she is also preferentially referred to the closest stroke center. If the patient is likely a candidate for ET only, he/she is preferentially referred to the closest CSC. If the patient is likely a candidate for both IVT and ET, the algorithm takes in consideration the likelihood of LVOS ($\approx 30\%$ versus $\approx 60\%$ to 85%) and the additional transportation time from the closest center to CSC. Figure 3 depicts the FAST-ED decision tree algorithm. Recommended (default) values for the maximal acceptable transportation delay depend on whether patients are within the intravenous tPA time window and on their FAST ED score, and can be manually adjusted by the regional administrator for the App (eg, Regional EMS Office, Figure 2). The default value is 30 minutes for patients with onset within the intravenous tPA window and FAST ED score of ≥ 4 . This 30-minute transportation delay window is supported by a recent analysis modeling different “Drip and Ship” scenarios across PSCs and CSCs in Canada and California.¹¹ For patients with onset outside the intravenous tPA window and FAST ED score of 2 to 3, the acceptable delay is also set at 30 minutes. Finally, for patients with onset outside the intravenous tPA window and FAST ED score of ≥ 4 , the acceptable delay is set at 60 minutes. If the delay is more than 60 minutes, the algorithm will suggest to consider calling air transport to CSC and will offer an option to contact the closest medical flight service or will indicate transport to the closest PSC offering Global Positioning System guidance.

Regional Adjustments and Future Improvements

To allow for better conformability to the needs and particularities of different geographic locations, the App allows for

many of the time variables to be adjusted by the App regional administrator (Figure 2). As regional leaderships continually refine and improve their stroke destination triage capabilities and options, additional optimization of the system choices will evolve, based on the feedback from regional hospitals about imaging results (LVOS) and the types of treatment received. For instance, the optimal FAST-ED scale cut offs might differ across rural and urban settings. Another possibility is the use of the average door-to-needle time for each individual center as opposed to the regional average time. This would lead to greater precision given differences in performance but will require greater data coordination by the regional stroke and EMS leaderships. Future versions of the App will integrate the FAST-ED platform with a videoconferencing tool that will allow for direct EMS videoconsultation with the receiving hospital stroke team and real-time ambulance location tracking.

Discussion

We describe the decision-making models included in the development of the first smartphone freeware application created to optimize the triage of patients with acute stroke to a CSC or to a PSC/ASRH. This decision can be made on-scene, at point-of-patient contact in the field based upon objective criteria, including a regional database of stroke centers, a small series of simple questions, and geo-positioning information available on most smartphones.

The hard criteria used to create the algorithms in this application were derived from pivotal clinical studies in acute stroke. The criteria related to maximum difference in transportation times to a CSC versus a PSC/ASRH were defined in conjunction with the regional stroke and EMS leadership and can be easily adjusted for different regions. Using simple questions that can be rapidly answered, the application aims to objectively guide the triage of patients with acute stroke, a decision that often involves a complex balance between offering care not only in the most expeditious manner but also at a stroke center capable of delivering the appropriate treatment for the patient in question. This decision is typically carried out under a lot of pressure, at a time when the clinical condition of the patient is critical, and when every minute lost might lower the patient’s chances of improved functional recovery.^{12,13} However, arriving fast at a stroke center might not be enough for some patients, especially those with LVOS who are most likely to benefit from advanced care and, in particular, from mechanical thrombectomy. Conversely, taking most patients to a CSC would be equally detrimental given the implications of delaying IVT, which is faster and cheaper than ET, and is the only accepted treatment for distal occlusion and lacunar strokes.^{14–16} Such a practice would not only have direct untoward consequences to the outcomes of these patients, but it would also adversely affect the long-term viability of the more geographically well-distributed PSCs and ASRHs ultimately leading to greater delays in stroke care. Moreover, the CSCs’ bed capacities would become increasingly saturated by patients who did not need advanced stroke care and could have been well cared for much closer to their communities, resulting in the escalation of more appropriate

patients being turned away (triage mismatches). Overtriage to CSCs may also unnecessarily prolong the period of time that a community has an ambulance out of service potentially delaying transportation and care for other patients requiring time-dependent interventions (ie, trauma, STEMI, sepsis etc.).

Unfortunately, clinical severity scales cannot unmistakably identify LVOS.¹⁷ In fact, a recent study demonstrated that the use of the published cutoffs for most triage scales would result in the improper referral of more than 20% of patients with LVOS to a center lacking neuroendovascular capability while applying cutoffs reducing the false-negative rate to 10% would result in transporting almost every patient to a CSC.¹⁸ However, the objective of these scales is not to replace vessel imaging but rather to use the best available information in the field to triage the destination of patients with stroke. Therefore, it is essential to highlight that the simple presence of an LVOS does not necessarily equate to a need for emergent thrombectomy. Indeed, whether patients with LVOS presenting with low NIHSS benefit from ET remains controversial.^{1,19} Moreover, LVOS patients with lower clinical severities theoretically have better collateral flow, which is associated with better natural history, higher chances of response to IVT, and potentially a longer treatment window for ET.²⁰ As such, it is reasonable if not more logical that most patients with LVOS and low NIHSS would be first evaluated at a closer PSC/ASRH to be assessed for IVT and undergo neurovascular imaging before the transportation to a more distant CSC.

The likelihood of LVOS can be estimated with a high degree of accuracy by utilizing the FAST-ED scale. In the STOPStroke (Screening Technology and Outcomes Project in Stroke) cohort (n=727, 33% LVOS), in which patients underwent CT angiography within the first 24 hours of stroke onset, FAST-ED had comparable accuracy in predicting LVOS to the full NIHSS and higher accuracy than Rapid Arterial Occlusion Evaluation (RACE) and Cincinnati Prehospital Stroke Scale (CPSS) (area under the receiver operating characteristic curve: FAST-ED=0.81 as reference; NIHSS=0.80, $P=0.28$; RACE=0.77, $P=0.02$; and CPSS=0.75, $P=0.002$).² Similar findings were seen in the Bernese Stroke cohort which comprises 1085 patients (60.5% LVOS) who underwent CTA or MRA within 6 hours of stroke onset. In this population, FAST-ED had again the best performance among several other clinical scales (area under the receiver operating characteristic curve: FAST-ED=0.847; NIHSS=0.846; RACE=0.831; CPSS=0.802).^{17,21} These results may reflect potential advantages of FAST-ED. FAST-ED scores 1 point for facial weakness while RACE scores up to 2 points. FAST-ED does not score any points for leg weakness while RACE scores up to 2 points. Adding the additional 3 points for motor weakness does not increase the ability to discriminate cortical versus subcortical lesions but may increase the chances of misdiagnosing a pure motor syndrome as an LVOS. This is particularly important because pure motor strokes represent $\approx 13\%$ of all strokes and as many as 85% of them are lacunar in pathogenesis.²² FAST-ED scores up to 2 points for gaze deviation while RACE scores only 1 point. This is theoretically disadvantageous for RACE because gaze deviation has been identified as the highest predictor of LVOS in at least 2 previous studies.^{4,17} Finally,

RACE computes 2 points for receptive aphasia (versus one point in FAST-ED) and no points for expressive aphasia (versus 1 point in FAST-ED). This brings redundancy for one cortical territory while providing no representation to an equally important one. CPSS only computes aphasia if it is global and as such provides no points for isolated expressive or receptive aphasia. Moreover, CPSS does not assess for neglect, making the evaluation of nondominant hemispheric strokes more limited. Despite the theoretical advantages of some scales they likely perform within a relatively similar range with only small differences in terms of ease to use and accuracy. As such, we believe that the main innovation brought by the FAST-ED App is related to its elaborate decision-making algorithm allowing for a quick assessment of different treatment options based on each patient's characteristics and field transportation times from point-of-patient contact. However, it is important to acknowledge that the decision algorithm heavily relies on the probability of LVOS as estimated by the FAST-ED scale, which has been primarily studied in hospital cohorts. Whether these estimates are similar for the hospital and prehospital settings is currently unknown. Future efforts should, therefore, concentrate on regional organization of stroke and EMS leaderships for the proper categorization of their local hospitals, the field validation of the FAST-ED scale, and the quantification of the effects of this App technology on transfer times, intravenous tPA and thrombectomy treatment rates, and the long-term outcomes of patients with acute stroke.

Conclusions

In conclusion, the FAST-ED smartphone application has a great potential to improve the triage of patients with acute ischemic stroke, as it seems capable to optimize resources, reduce hospital arrivals times, and maximize the use of both intravenous tPA and ET ultimately leading to better clinical outcomes. Future field studies are needed to properly evaluate the impact of this tool in stroke outcomes and resource use.

Disclosures

RGN: Stryker Neurovascular (Trepo-2 Trial Principal Investigator—modest; DAWN Trial Principal Investigator—no compensation, TREVO Registry Steering Committee—no compensation), Medtronic (SWIFT Trial Steering Committee—modest; SWIFT-Prime Trial Steering Committee—no compensation; STAR Trial Angiographic Core Laboratory—significant), Penumbra (3D Separator Trial Executive Committee—no compensation), Neuravi (ARISE-2 Steering Committee—no compensation), Genentech (Physician Advisory Board—modest), Allm Inc (Physician Advisory Board—no compensation). The other authors report no conflicts

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