Published in final edited form as:

Curr Opin Neurol. 2016 February ; 29(1): 14–19. doi:10.1097/WCO.0000000000000281.

Pre and intrahospital workflow for acute stroke treatment

Charles Kircher^a, Natalie Kreitzer^{a,b}, and Opeolu Adeoye^{a,b,c}

^aDepartment of Emergency Medicine, University of Cincinnati, Ohio, USA

^bUniversity of Cincinnati Neuroscience Institute, Ohio, USA

^cDepartment of Neurosurgery, University of Cincinnati, Cincinnati, Ohio, USA

Abstract

Purpose of review—With the recent demonstration of the effectiveness of rapid recanalization of large vessel occlusions in acute ischemic stroke, it is important to assess the current status of pre and intrahospital workflow for acute stroke.

Recent findings—We will review trends in the evaluation and treatment of acute stroke and offer suggestions for how best to advance the workflow for acute stroke care in the coming years.

Summary—Future research is needed for: field use of clinical scores for predicting large vessel occlusions, telemedicine to facilitate prehospital triage, and pre and intrahospital processes for optimizing stroke care delivery.

Keywords

delay; emergency department; emergency medical services; triage

INTRODUCTION

Since publication of the National Institutes of Neurological Disorders and Stroke recombinant tissue plasminogen activator (rt-PA) stroke trial in 1995 [1], faster times to delivery of intravenous (i.v.) rt-PA in eligible patients have been recommended for improving outcomes following acute ischemic stroke (AIS) [2]. In patients with confirmed large vessel occlusions (LVO), the primacy of rapid recanalization and reperfusion was demonstrated in multiple clinical trials in the past year (Fig. 1a and b) [3–7]. Thus, it is a critical and opportune time to reevaluate pre and intrahospital workflow for acute stroke care. In this review, we will discuss trends in pre and intrahospital acute stroke workflow in the past 20 years, the current state of the art, and opportunities for further improvement in the acute evaluation and treatment of stroke patients.

Correspondence to Opeolu Adeoye, MD, MS, Department of Emergency Medicine, University of Cincinnati, 231 Albert Sabin Way, ML 0769, Cincinnati, OH 45267, USA. Tel: +1 513 558 3117; fax: +1 513 558 6434; opeolu.adeoye@uc.edu.

Financial support and sponsorship

None.

Conflicts of interest

There are no conflicts of interest.

PREHOSPITAL CARE OF ACUTE STROKE

Recognition of stroke symptoms

Timely workup and treatment of patients with AIS begins with recognition of stroke-like symptoms by patients, the public and/or emergency medical services (EMS) personnel. A recent review suggests that educational intervention can impact stroke recognition by the public and EMS, and improve metrics such as early arrival and time to treatment [8]. However, in a Greek study, 24% of study participants surveyed did not know any stroke symptoms [9]; in Spain, 11% did not know any symptoms [10]; and, in the United States, 32% did not know any symptoms [11]. Both the Los Angeles Prehospital Stroke Screen and Cincinnati Prehospital Stroke Scale (CPSS) may be used by EMS providers to rapidly evaluate a patient for acute stroke symptoms. A recent comparison of the two showed that they performed with nearly identical sensitivity (80% for CPSS vs. 74% for Los Angeles Prehospital Stroke Screen and specificity (48%) [12]. In an analysis of 371 988 AIS patients transported by EMS and enrolled in the American Heart Association's (AHA) Get With The Guidelines stroke registry from 1 April 2003 to 31 March 2011, although prenotification was associated with shorter door-to-computed tomography, door-to-needle (DTN), and symptom onset-to-needle times, prenotification did not occur in one out of three EMS transports [13]. Future efforts should be geared toward further improving public and EMS knowledge of the signs and symptoms of stroke, and improving prenotification rates by EMS prior to transporting potential stroke patients to nearby emergency departments (EDs).

Minimizing emergency medical services scene time

A 2007 AHA statement for EMS agencies recommended EMS providers spend less than 15 min on scene evaluating potential AIS patients [14]. In a 2009 analysis of 86 EMS systems in North Carolina, a protocol specific scene time limit of 15 min reduced scene times by 2.2 min in those systems with specified scene times compared with those without; overall mean scene time was 15.9 min [15]. The authors concluded that EMS systems can modestly reduce on-scene times with specified limits on scene time. Further, the urgency created by such specified limits may lead to higher rates of prenotification, which has anticipated benefits on times to treatment [13]. Less time on scene should not preclude EMS transport of caregivers or family members along with the patient to provide additional information regarding the patient's last seen well (LSW) time and past medical history.

Destination of ambulances

Previously, it was recommended that AIS patients who may be eligible for i.v. rt-PA be transported as quickly as possible to the closest primary stroke center (PSC) or the closest acute stroke ready hospital (ASRH). Given the recent advances in endovascular therapy for patients with confirmed LVO [3–5], prehospital identification of patients with potential LVO is an emerging priority for EMS providers. Such patients may warrant preferential triage from the prehospital setting directly to the closest comprehensive stroke center (CSC), potentially bypassing closer ASRHs/PSCs on the way to the CSC, which has 24/7 endovascular therapy capability. A recent review of the Los Angeles County EMS system demonstrated that by triaging patients to certified acute stroke centers, patients had a nearly five times increase in the rate of acute stroke care at designated stroke centers, an 18.6%

increase in clinical trial enrollment, and a statistically insignificant decrease in EMS run time [16[■]]. As of this writing, there is no universally accepted tool for identifying patients with potential LVO in the prehospital setting, although various approaches have been proposed [17,18], including our Cincinnati Stroke Triage and Assessment Tool (C-STAT, previously called CPSSS) (Table 1).

A reliable prehospital screening tool for predicting LVOs is essential given that delays in reperfusion can have a negative impact on patients [19[■]]. Although confirmation and validation of the various screening tools are ongoing, EMS protocols should include an estimate of stroke severity with instructions to triage ‘severe’ strokes to CSCs capable of offering endovascular therapy provided travel time to the CSC is not markedly greater than travel time to the ASRH/PSC. Patients without severe strokes should be triaged to ASRHs or PSCs as per current AHA recommendations. EMS systems with long transport times or limited access to CSCs may need to consider close coordination with helicopter EMS (HEMS) for transport of stroke patients to endovascular therapy-capable centers from the scene or from a hospital after imaging and rt-PA administration, if applicable.

Prehospital mobile stroke units

We are aware of specialized mobile stroke units (MSUs) that are currently deployed in Berlin, Germany; Houston, Texas; and Cleveland, Ohio. MSUs have generated great enthusiasm within the stroke community. Recent data from the Berlin and Houston pilot projects point to their clinical efficacy in acute stroke treatment. Utilizing a portable CT scanner, remote review of CT by a neuroradiologist, and onboard point of care testing of international normalized ratio and other relevant laboratory parameters, the Berlin Stroke Emergency Mobile Unit (STEMO) group was able to achieve median call-to-needle time of 62 min for prehospital thrombolysis compared with 98 min average for historical controls in the same city [20]. Of all STEMO-treated patients, 31% were treated within 60 min of LSW (the ‘golden hour’) compared with 4.9% of patients treated in hospital with no significant change in overall mortality, and a higher likelihood [odds ratio (OR) 1.93] of being discharged home [21]. The STEMO ambulance improved triage of patients with stroke like symptoms; fewer patients with stroke like symptoms may be sent to a hospital without stroke care and fewer patients with intracerebral hemorrhage may be sent to hospitals without neurosurgical capability [22[■]]. A very small number of patients who qualified for endovascular therapy were evaluated by the STEMO unit. Care of these five patients demonstrated a substantially shorter time to endovascular therapy (82 vs. 165 min) [23].

Significant questions remain regarding the cost-effectiveness and sustainability of MSUs if used in a variety of communities. A cost-effectiveness analysis of the STEMO unit estimated that the avoidance of disability associated with earlier stroke treatment was approximately €32 456/QALY gained [24]. This was achieved by treating 85 more patients with i.v. rt-PA and by treating higher proportions of patients faster. Also, both the STEMO and Houston programs have a physician onboard the MSU, whereas the Cleveland program is under telemedicine direction by a physician at the hospital. Comparative studies of the most efficient yet timely means of evaluating, triaging, and treating stroke patients in the prehospital setting are warranted.

Other emerging prehospital transport issues

With the advent of endovascular therapy as a proven treatment for AIS patients with LVO, hospital systems and regional EMS networks must revisit protocols for EMS triage of potential stroke patients. Where feasible, HEMS transport for transfer to an endovascular therapy-capable center is appropriate. HEMS personnel can administer on-scene NIHSS evaluation with moderate to good interrater reliability when compared with in-hospital stroke consultants [25]. Earlier activation and mobilization of the in-hospital stroke team may lead to faster treatment times.

Our university-associated HEMS group responds both to rural ‘scene stroke’ calls when requested by EMS providers and for interhospital transfers. It is important to note that this system is useful only in instances where ground EMS transport to a stroke center will be prolonged or the patient has had an initial acute stroke evaluation, including imaging, stroke team consultation where appropriate, and initiation of i.v. rt-PA at the referring hospital. Telemedicine may also facilitate prehospital stroke triage and treatment, as is currently done by the Cleveland MSU. Expanded use of telemedicine is discussed further below.

INTRAHOSPITAL CARE OF ACUTE ISCHEMIC STROKE

It is imperative for emergency departments to have an established workflow for the treatment of AIS to minimize DTN times. A complex sequence of events must occur prior to rt-PA administration, including a noncontrast head CT, i.v. placement, brief discussion of eligibility and safety of rt-PA with the patient or family, and lab review if necessary. In eligible patients, endovascular therapy should proceed rapidly and this may entail performance and review of CT angiography (CTA) of the head and neck, other advanced imaging and rapid mobilization of the endovascular therapy team and resources.

Stroke protocols

Numerous studies have demonstrated that implementation of a ‘code stroke’ improves DTN time. In one example, the protocol included CT prenotification of an incoming patient, CT performed in less than 25 min after arrival, rt-PA administration in a specialized stroke ICU equipped with beds that could rapidly weigh patients and staffed with nurses adept at rt-PA administration, and neurologist evaluation within 15 min of patient arrival. These interventions reduced DTN time significantly (88–51 min, $P < 0.001$) and reduced the percentage of patients treated under 60 min (14.3–71.3%, $P < 0.001$) [26]. In another example, a specialized neurology emergency department implemented a system where EMS delivers the patient directly to the CT scanner, and a neurology emergency team is present; achieved DTN was 44 min [27]. We anticipate that even faster DTN times will be achieved as systems of acute stroke care continue to mature. The best approach to improving DTN in a given hospital often depends on local barriers specific to individual systems of care. A collaboration between EMS, emergency department, radiology, and neurology personnel, coupled with real time systematic analyses of delays in DTN times will identify areas to target for improvement.

Telemedicine

Telemedicine has been used increasingly over the past decade in the management of AIS. The largest described series of telemedicine evaluated and treated AIS patients are out of a rural telestroke network in Bavaria, Germany. Of 54 804 stroke cases over a nine-year period, DTN times decreased from 80 min (interquartile range, 68–101) during the early phase to 40 min (interquartile range, 29–59) [28]. As mentioned above, telemedicine has been coupled with the MSU in Cleveland, Ohio, and routing of ambulances to designated stroke centers improves the rate of patients cared for at these centers [16[■]]. No distinction was made between ASRH, PSCs, and CSCs. With the advent of endovascular therapy, higher fidelity in prehospital triage is warranted, especially since CSCs may be deluged with patients that do not necessarily need CSC care, including nonstroke cases, while potentially delaying onset to i.v. rt-PA times in eligible AIS patients because of bypassing of ASRHs/ PSCs on the way to the CSC.

Endovascular therapy

We have already discussed the multiple trials published in the past year that demonstrated the benefit of endovascular therapy in eligible patients [3–7]. We have also discussed the workflow challenge of getting the right patient to the right hospital. Once a patient arrives at an endovascular therapy-capable hospital, there remains a challenge of promptly recognizing endovascular therapy eligibility, and concurrently performing the necessary workup, while mobilizing the relevant teams to minimize emergency department arrival to groin puncture and arterial recanalization times. A major delay between imaging and patient arrival to the neurointervention suite has been described [29]. A quality improvement project, including parallel workflow between the emergency department, neurology, and neurointervention in preparation for the patient undergoing endovascular therapy resulted in a 36-min reduction in median door-to-puncture time (143 vs. 107 min; $P < 0.0001$) [29]. The Endovascular Treatment for Small Core and Anterior Circulation Proximal Occlusion with Emphasis on Minimizing CT to Recanalization Times (ESCAPE) trial set a picture-to-puncture goal of 60 min in the endovascular therapy arm and achieved a median time of 51 min [6]. As of this writing, there are no agreed upon time targets to enhance hospital workflow for endovascular therapy patients. However, the metrics of door-to-puncture and picture-to-puncture are worthy of being adopted as quality initiatives to track in endovascular therapy-eligible AIS cases.

Advanced neuroimaging

The Canadian stroke best practice guidelines for 2015 [30[■]] recommend that all patients who present in the treatment time window should have vascular imaging (CTA or CT perfusion) [30[■]]. The AHA also recommended CTA in its 2015 focused statement on endovascular therapy, but described the benefits of CT perfusion or diffusion and perfusion-weighted imaging, for making endovascular therapy decisions as ‘unknown’ [31]. At centers that are equipped to obtain such imaging, a rapid CT/CTA will allow simultaneous evaluation of eligibility for rt-PA alone vs. rt-PA plus subsequent endovascular therapy. Thus in patients who may be eligible for endovascular therapy, we recommend CT/CTA be

performed expeditiously. Use of perfusion imaging in acute clinical decision making is an area of ongoing research.

CONCLUSION

The current state of the art for AIS management entails symptom recognition by patients/bystanders, activation of EMS, rapid transport to a stroke capable hospital or prehospital engagement of an MSU, ascertainment of eligibility for i.v. rt-PA and/or endovascular therapy, and expeditious administration of either or both therapies. In this paradigm, prehospital, and intrahospital workflow offer opportunities for novel research and improvement in patients/bystanders seeking care in a timely fashion, whereas EMS and hospital providers facilitate timely care delivery.

Acknowledgments

None.

REFERENCES AND RECOMMENDED READING

Papers of particular interest, published within the annual period of review, have been highlighted as:

■ of special interest

■■ of outstanding interest

1. Tissue plasminogen activator for acute ischemic stroke. The National Institute of Neurological Disorders and Stroke rt-PA Stroke Study Group. *N Engl J Med.* 1995; 333:1581–1587. [PubMed: 7477192]
2. Jauch EC, Saver JL, Adams HP Jr, et al. Guidelines for the early management of patients with acute ischemic stroke: a guideline for healthcare professionals from the American Heart Association/American Stroke Association. *Stroke.* 2013; 44:870–947. [PubMed: 23370205]
3. Berkhemer OA, Fransen PS, Beumer D, et al. A randomized trial of intraarterial treatment for acute ischemic stroke. *N Engl J Med.* 2015; 372:11–20. [PubMed: 25517348]
4. Campbell BC, Mitchell PJ, Kleinig TJ, et al. Endovascular therapy for ischemic stroke with perfusion-imaging selection. *N Engl J Med.* 2015; 372:1009–1018. [PubMed: 25671797]
5. Saver JL, Goyal M, Bonafe A, et al. Stent-retriever thrombectomy after intravenous t-PA vs. t-PA alone in stroke. *N Engl J Med.* 2015; 372:2285–2295. [PubMed: 25882376]
6. Goyal M, Demchuk AM, Menon BK, et al. Randomized assessment of rapid endovascular treatment of ischemic stroke. *N Engl J Med.* 2015; 372:1019–1030. [PubMed: 25671798]
7. Jovin TG, Chamorro A, Cobo E, et al. Thrombectomy within 8 hours after symptom onset in ischemic stroke. *N Engl J Med.* 2015; 372:2296–2306. [PubMed: 25882510]
8. Mellon L, Doyle F, Rohde D, et al. Stroke warning campaigns: delivering better patient outcomes? A systematic review. *Patient Relat Outcome Meas.* 2015; 6:61–73. [PubMed: 25750550]
9. Hatzitolios AI, Spanou M, Dambali R, et al. Public awareness of stroke symptoms and risk factors and response to acute stroke in Northern Greece. *Int J Stroke.* 2014; 9:E15. [PubMed: 24798041]
10. Lundelin K, Graciani A, Garcia-Puig J, et al. Knowledge of stroke warning symptoms and intended action in response to stroke in Spain: a nationwide population-based study. *Cerebrovasc Dis.* 2012; 34:161–168. [PubMed: 22907330]
11. Kleindorfer D, Khoury J, Broderick JP, et al. Temporal trends in public awareness of stroke: warning signs, risk factors, and treatment. *Stroke.* 2009; 40:2502–2506. [PubMed: 19498187]

12. Asimos AW, Ward S, Brice JH, et al. Out-of-hospital stroke screen accuracy in a state with an emergency medical services protocol for routing patients to acute stroke centers. *Ann Emerg Med*. 2014; 64:509–515. [PubMed: 24746847]
13. Lin CB, Peterson ED, Smith EE, et al. Emergency medical service hospital prenotification is associated with improved evaluation and treatment of acute ischemic stroke. *Circ Cardiovasc Qual Outcomes*. 2012; 5:514–522. [PubMed: 22787065]
14. Acker JE 3rd, Pancioli AM, Crocco TJ, et al. Implementation strategies for emergency medical services within stroke systems of care: a policy statement from the American Heart Association/American Stroke Association Expert Panel on Emergency Medical Services Systems and the Stroke Council. *Stroke*. 2007; 38:3097–3115. [PubMed: 17901393]
15. Patel MD, Brice JH, Moss C, et al. An evaluation of emergency medical services stroke protocols and scene times. *Prehosp Emerg Care*. 2014; 18:15–21.
16. Sanossian N, Liebeskind DS, Eckstein M, et al. Routing ambulances to designated centers increases access to stroke center care and enrollment in prehospital research. *Stroke*. 2015; 46:2886–2890. The article describes a cohort of patients who were preferentially taken to acute stroke centers rather than nearest hospital. This protocol led to an increase in the number of patients who received acute stroke treatment without an increase in prehospital times. [PubMed: 26265130]
17. Katz BS, McMullan JT, Sucharew H, et al. Design and validation of a prehospital scale to predict stroke severity: Cincinnati Prehospital Stroke Severity Scale. *Stroke*. 2015; 46:1508–1512. [PubMed: 25899242]
18. Perez de la Ossa N, Carrera D, Gorchs 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. [PubMed: 24281224]
19. Khatri P, Yeatts SD, Mazighi M, et al. Time to angiographic reperfusion and clinical outcome after acute ischaemic stroke: an analysis of data from the Interventional Management of Stroke (IMS III) phase 3 trial. *Lancet Neurol*. 2014; 13:567–574. Time to reperfusion was shown to have an impact on clinical outcome, with increased times leading to a decreased likelihood of a good clinical outcome in the IMS III cohort. [PubMed: 24784550]
20. Weber JE, Ebinger M, Rozanski M, et al. Prehospital thrombolysis in acute stroke: results of the PHANTOM-S pilot study. *Neurology*. 2013; 80:163–168. [PubMed: 23223534]
21. Ebinger M, Kunz A, Wendt M, et al. Effects of golden hour thrombolysis: a Prehospital Acute Neurological Treatment and Optimization of Medical Care in Stroke (PHANTOM-S) substudy. *JAMA Neurol*. 2015; 72:25–30. [PubMed: 25402214]
22. Wendt M, Ebinger M, Kunz A, et al. Improved prehospital triage of patients with stroke in a specialized stroke ambulance: results of the prehospital acute neurological therapy and optimization of medical care in stroke study. *Stroke*. 2015; 46:740–745. Specialized stroke ambulances, such as STEMO in Germany, have been deployed in recent years. This analysis compared patients who underwent prehospital triage with STEMO vs. nonstroke ambulances. STEMO improved the triage of patients with ischemic strokes to hospitals with specialized stroke units, and decreased the number of patients with intracerebral hemorrhage triaged to hospitals without neurosurgical capabilities. [PubMed: 25634000]
23. Cerejo R, John S, Buletko AB, et al. A mobile stroke treatment unit for field triage of patients for intraarterial revascularization therapy. *J Neuroimaging*. 2015; 25:940–945. [PubMed: 26179631]
24. Gyrd-Hansen D, Olsen KR, Bollweg K, et al. Cost-effectiveness estimate of prehospital thrombolysis: results of the PHANTOM-S study. *Neurology*. 2015; 84:1090–1097. [PubMed: 25672925]
25. Kesinger MR, Sequeira DJ, Buffalini S, Guyette FX. Comparing National Institutes of Health Stroke Scale among a stroke team and helicopter emergency medical service providers. *Stroke*. 2015; 46:575–578. [PubMed: 25538202]
26. Chen CH, Tang SC, Tsai LK, et al. Stroke code improves intravenous thrombolysis administration in acute ischemic stroke. *PLoS One*. 2014; 9:e104862. Numerous studies have now reported that the development of protocols within emergency departments that aim to decrease the time to treatment of strokes improves stroke care. Development of a ‘code stroke’

significantly increased the number of patients treated with i.v. tPA, and decreased the door to needle time. [PubMed: 25111200]

27. Binning MJ, Sanfillippo G, Rosen W, et al. The neurological emergency room and prehospital stroke alert: the whole is greater than the sum of its parts. *Neurosurgery*. 2014; 74:281–285. [PubMed: 24276505]
28. Muller-Barna P, Hubert GJ, Boy S, et al. TeleStroke units serving as a model of care in rural areas: 10-year experience of the TeleMedical project for integrative stroke care. *Stroke*. 2014; 45:2739–2744. [PubMed: 25147327]
29. Mehta BP, Leslie-Mazwi TM, Chandra RV, et al. Reducing door-to-puncture times for intra-arterial stroke therapy: a pilot quality improvement project. *J Am Heart Assoc*. 2014; 3:e000963. [PubMed: 25389281]
30. Casaubon LK, Boulanger JM, Blacquiére D, et al. Canadian Stroke Best Practice Recommendations: Hyperacute Stroke Care Guidelines, update 2015. *Int J Stroke*. 2015; 10:924–940. The Canadian stroke guidelines recommend that all patients should have CT angiography at the same time as the noncontrast head CT. By rapidly identifying large vessel occlusions, timely delivery of endovascular therapy is feasible. [PubMed: 26148019]
31. Powers WJ, Derdeyn CP, Biller J, et al. 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. [PubMed: 26123479]

KEY POINTS

- Prehospital stroke assessments now require estimation of stroke severity, not just stroke recognition.
- Triage of severe stroke cases directly to endovascular therapy-capable hospitals offers the best chance of reaping the potential benefits of ET.
- Endovascular therapy-capable hospitals should develop workflows that facilitate rapid evaluation and rapid delivery of endovascular therapy in eligible patients.
- Future research is needed for: field use of clinical scores for predicting LVO, telemedicine to facilitate prehospital triage, and pre and intrahospital processes for optimizing AIS care delivery.

FIGURE 1.

(a) Prethrombectomy angiogram in an 18-year-old man who suddenly collapsed. (b) Postthrombectomy angiogram showing recanalization.

Table 1

Comparison of the Cincinnati Stroke Triage and Assessment Tool^a and Rapid Arterial occlusion Evaluation^b prehospital scales for predicting large vessel occlusions

	C-STAT	RACE
Derivation, (N)	624	654
Validation in independent data set	Yes	Yes
Evaluated in prehospital setting	No	Yes
Sensitivity for LVO	83%	85%
Specificity for LVO	40%	67%

C-STAT, Cincinnati Stroke Triage and Assessment Tool; LVO, large vessel occlusions; RACE, Rapid Arterial occlusion Evaluation.

^aPreviously referred to as the Cincinnati Prehospital Stroke Severity Scale [17].

^bRACE scale [18].