Review Article

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Prehospital stroke care, a narrative review

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Abstract:

Stroke is a leading cause of disability in the United States and current treatment for stroke is limited to two modalities with well-defined time restraints. The prehospital setting is a significant and relatively easy setting for innovation in stroke care, as the most clinical decisions are made within the first several hours of symptom onset. In this review, we look at recent innovations in improving prehospital care for acute stroke including the conception of mobile stroke units, the ongoing development of stroke models for emergency providers, barriers to prehospital care, and the innovation of new telephone applications. Although there are notable improvements in acute stroke care, additional research is needed to further improve on current models and technologies.

Keywords:

Algorithm, application, mobile, prehospital, stroke

Introduction

Stroke remains one of the leading causes of morbidity, disability, and death in the United States and industrialized countries.[1] Stroke not only affects the individual patient but also applies a remarkable cost to society due to the loss of productivity of labor and significant utilization of long-term nursing care. Stroke's notable economic impact on the population is expected to continue to increase due to an expanding and aging population.[2]

Despite recent innovations within the past two decades that led to restricted treatment in the acute setting for stroke, identifying suitable patients in a time sensitive manner for thrombolysis remains a fundamental limitation. To this end, only 2%–5% of ischemic stroke patients receive intravenous thrombolysis due to the strict 4.5 h window.[3] Within the last several years, breakthroughs in acute reperfusion therapies including intra-arterial therapy (IAT) has added another layer of complex decision making in the algorithm for the management of acute stroke. Notwithstanding the extended therapeutic window afforded by the recent DAWN trial, timely access to a specialized hospital capable of IAT continues to remain another barrier to therapy.

The overall consensus remains that accurate prehospital evaluation and rapid transport to a hospital with the appropriate level of neurologic expertise remains pivotal to maximizing therapeutic benefit to patients.[4] Several culprits have been identified as leading causes to delay of treatment. Identification of stroke syndromes amenable to treatment is paramount but has proven difficult before hospital evaluation.[5] Barriers faced by emergency medical services (EMS) including extraction, patient access, and communication remain challenges to overcome.[6] Access to the appropriate level of care, especially to hospitals capable of intra-arterial therapies remain elusive. This is particularly a cogent challenge in the rural regions.[7]

After a review of the existing literature, there exists only a limited amount of original

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research to confront this emerging problem of prehospital stroke care. The authors recognize that there are no prehospital evaluation scales that currently exist with high enough fidelity and simplicity for EMS to identify stroke syndromes versus stroke mimics.[5] Development of ground and air mobile stroke units (MSUs) remains in its infancy,[8] and the use of such tools are limited to select metropolitan regions across the world.[7] Theoretical-based algorithms for triage and delivery of care in stroke patients have yet to be field tested.[9] The widespread use, cost-effectiveness, and feasibility of adaption by a variety of healthcare systems remains to be tested. Notably, further innovation and research in prehospital stroke management are needed to impact overall outcomes of a patient with strokes.

Methods

Search strategy

Review of the literature was conducted through Internet search on public access website PubMed and Medline databases between 1998 and 2018. Keywords utilized included prehospital stroke care mobile stroke units, stroke triage, emergency medical services, and screening scales. Titles and abstracts were filtered using inclusion and exclusion criteria by authors to ensure agreement. Titles that were felt to meet criteria were subjected to further review.

Inclusion/exclusion criteria

We considered original articles involved in the evaluation of prehospital stroke management. Original research involving evaluation of triage in specialized ambulances with telestroke capabilities and MSUs were included. Papers on prehospital assessment scales to identify stroke syndromes and stroke mimics were retained. Finally, prehospital stroke algorithms for transport and triage literature were included in the review.

Results

Our search yielded 157 articles on MEDLINE, of those, 34 were duplicates, 45 were editorials, and 59 were original research articles. Of those original research, further 25 were rejected based off title, 13 were rejected based off abstract and title, and three were rejected after review of the full article.

Mobile stroke units

MSUs were conceived as a bridge to in-hospital stroke care, allowing stroke experts to have expedited evaluation of the patients in the field, and are usually conducted by a stroke-trained neurologist or emergency medicine physician.[10] The primary goal of MSUs is to increase the efficiency of the initial stroke evaluation. Early assessment care by emergency technicians and trained nurses also can be completed before arrival to the hospital. This includes completing a prehospital stroke scale such as the National Institute of Health Stroke Scale, face, arm, speech, time (FAST), Los Angeles prehospital stroke screen, or Cincinnati Prehospital Stroke Scale among others.[11]

Several MSUs allow for telecommunication with stroke-trained physicians, with the assistance of emergency medical personnel or nurse, to complete initial neurological evaluation in the ambulance. Point of care laboratory markers can be drawn including evaluation of creatinine, blood glucose, the international normalized ration for coagulation time, and platelet count. Even more significantly, MSUs can be equipped with neuroimaging apparatus, primarily compact, mobile helical multidetector row computed tomography (CT) scanners capable of obtaining rapid sequence axial imaging that is then sent to the neurologist and radiologist through uploading to cloud and radio imaging servers for interpretation and thereby reducing the time of image acquisition. In addition to plain CT, additional vessel imaging capabilities have been explored.[12] This allows for several early triage decisions to be made. Identification of intracranial hemorrhage (ICH) rather than ischemic etiology leads to alternate treatment algorithm, including separate targets for blood pressure control, identification, and reversal of anticoagulation agents, and transportation to a hospital with neurosurgical and neurocritical care capabilities. By determining the absence of ICH and other contraindications to thrombolysis before hospital arrival, tissue plasminogen activator (tPA) can be more efficiently prepared for delivery on patients arrival to the receiving hospital.

CT angiography provides additional benefit in identifying large vessel occlusions (LVO). The existence of LVO are treated with thrombolysis and IAT, and the presence of LVO can alter the trajectory of an ambulance to a nearby facility capable of IAT (comprehensive stroke center) rather than treatment center that only provides tPA.[13]

Several limitations were identified in studies involving MSUs. Most notably, major outcome studies have not yet been investigated. While theoretically probable, it remains unclear if the utilization of MSUs can clearly change short-term and long-term patient outcomes. Studies evaluating post hospitalization modified Rankin scores, and other disability scales controlled non-MSU cases have not been explored. The evaluation of cost-effectiveness of MSU on large scales with varying populations and regions has not been fully elucidated. Separate and even more limited evaluation of air MSUs exists, which may benefit rural populations with limited access to IAT. Benefit of these units also has not been explored.

Algorithms and scoring models

Several evidence-based scoring systems have been validated in prospective trials. The purpose of such scoring systems, in its most ideal form, aims to help emergency medical personnel to accurately identify and classify patients with acute neurological manifestations into stroke syndromes and nonstroke syndromes.[14] A graded system can relate the probability that a neurologic presentation to the likelihood that it is vascular event. The architype scoring system should accomplish two criteria: balancing simplicity of use by EMS providers with high clinical specificity and sensitivity in identifying an acute stroke.

A study by Geisler *et al.* evaluated FAST test and Telestroke mimic stroke scale (TM-score) for its diagnostic value in differentiating patient's with ischemic strokes, transient ischemic attacks, and intracerebral hemorrhages compared to stroke mimics such as seizures, migraines, and hypoglycemia. These mimics of acute vascular syndromes should be identified early on to avoid unnecessary deployment and recruitment of stroke resources, such as in hospital emergency medicine personal, specialized laboratory and pharmacy technicians, and interventional radiology and anesthesiology members. Authors concluded there is value in calculating both scores to help differential true acute cerebrovascular syndromes and its mimics, but its adaptability and generalization is limited as no large prospective study exists.

Another prospective comparative study by Pickham *et al.* in Santa Clara County, California attempted to improve the accuracy of FAST stroke scale employed by many paramedics in the region by adding two additional scoring criteria Balance-Eyes-Face-Arm-Speech-Time. The goal was to increase the predictive value of stroke identification, specifically to increase sensitivity to posterior circulation stroke syndromes. The outcome of the analysis revealed only facial droop and arm weakness were independent predictors, but the addition of these two variables did not improve the accuracy of detection. To date, there remains no robust algorithm, especially prehospital scoring criteria, to saliently identify features of posterior circulation, namely, brainstem syndrome.

A group based out of the University of Calgary, Canada sought to optimize transport algorithms through computational modeling.[9] Based on existing clinical trial data with patients identified to have LVOs, the study enumerated strategies on transport and treatment based on the location of endovascular and thrombolysis centers. This study quantified treatment times for thrombolysis and median transport times that were established based off prior clinical stroke trials. Using these integrated variables, the authors were able to optimize transport strategies (administer alteplase at thrombolysis only center and then transport to thrombectomy or to transport directly to thrombectomy center despite passing nearby thrombolysis only hospital). Strategies proposed by this model remain to be empirical validated.

A very recent study by Zhao *et al*. in stroke[15] that describes a new algorithm called ACT-FAST which uses a three-step evaluation criteria that includes: (1) arm drift within 10 s, (2) language difficulty if left arm is affected or neglect if right arm is affected, and (3) stroke mimic screen. They found that they had an overall accuracy of 81.7%, the sensitivity of 85.7%, and specificity of 93.5% in identifying LVOs, which is higher than all other existing scoring models. Again broad generalizability and adaptability remain to be demonstrated in multicenter large randomized prospective trials.

Evaluation of barriers to prehospital care

There is little doubt that the effectiveness of prehospital care and evaluation relies heavily on expertise and optimization of EMS as they often are the first medically trained personnel to evaluate stroke patients. Li *et al.* sought to elucidate factors that preclude effective evaluation and delivery of such services. Factors that were identified as barriers included initial access to patients after they receive a dispatch. Often the fire department was secondarily involved to open locked doors by forced entry. Communication was also listed as another major barrier. The idea that patient's either without English proficiency or other factors such as ethnic, cultural, or health literacy may play a role in limiting effective communication. Although it was not exactly clear what such barriers to communicate were entailed in this study. Extraction tends to be more difficult, especially with stroke patients with limited mobility due to motor weakness, changes in perception or altered level of awareness. These factors that were identified are best addressed through more dedicated evaluation through a prospective study in each of these factors. It was noteworthy, that despite barriers there was no major delay in receiving intravenous alteplase in the nonbarrier group compared with the ones with significant barriers.

Stroke applications

Several studies have looked at the use of telephone applications to improve prehospital stroke care. A study published by Nogueira *et al*. in stroke[16] details the design of an application that helps EMS decide which hospital to bring the patient to based on clinical symptoms, time of onset, and blood thinning medications. Notably, this application uses GPS location as well as database on all regional comprehensive stroke centers to make a calculated decision for which hospital a patient should be directed. The primary decision point involves identifying

LVO versus small vessel strokes and identifying the closest comprehensive stroke center versus primary stroke center, respectively, in each decision.

A study performed by Dickson *et al*. in 2016[17] showed the utility of an application that transmits data from EMS providers directly to the ED and stroke team. This application allows from information such as photographs, weight, height, time of last known normal, and contraindications for tPA to be viewed. They found in this study of 85 stroke patients that their application reduced mean door to needle time by 40 min. Notably, this application has blossomed into a large medical startup.

Hidlay *et al*. in 2018[18] published a report that compared the accuracy of radiologists reviewing images on a smartphone versus the traditional picture archiving and communication workstation (PACS) to identify LVOs on CTA. They found 100% diagnostic accuracy for all 76 cases for both PACS and smartphone reads, with high reliability between radiologists. They went on to conclude that in the acute setting, experienced neuroradiologists are most likely to reliably identify LVOs on smartphone devices, which may increase the efficiency of treatment for these patients.

Emerging technologies in stroke and it's relevancy to prehospital care

There is a paucity of preclinical and early clinical technologies on the horizon that can be translated to real-world applications. Nevertheless, these unproven emerging entities may 1 day alter the landscape of prehospital stroke care.

Recent studies have shown that near-infrared spectroscopy can be utilized to identify early brain ischemia in acute stroke patients without the need for CT (Terborg *et al*., 2007).[19] In a limited study of cadavers and patients with acute ischemic stroke, Moreau *et al*.[20] validated the principle that a noninvasive device with frequency domain near-infrared spectroscopy can detect regions of the brain with acute hypoxia. Utilizing a photomultiplier probe that is placed against the frontal scalp among other regions, the device is capable of detecting ischemic brain regions with very low oxygen saturation. However, the sensitivity of the probe to small and large volume ischemia remains to be elucidated. Current pilot studies are underway investigating this noninvasive method of monitoring patients in and around the early post-stroke period.[21] It may be potentially feasible for near-infrared technology to be used in the evaluation of large volume ischemic stroke and adapted for prehospital stroke evaluation. Small, mobile probes could 1 day be incorporated into all emergency medical vehicles and serve as a cost-effective screening tool without the need for CT scanners built into every ambulance.

Discussion

Stroke remains a leading cause of morbidity and mortality in the United States. Although significant research has gone into stroke treatment, tPA and thrombectomy remain the primary two treatment modalities for ischemic stroke in a time-limited manner. Recent studies such as the DAWN trial have increased the treatment window for LVO and thereby increased the potential for recovery, but have also complicated the decisions in the acute stroke setting. MSUs are one way in which stroke providers are trying to get additional patient information before a patient's arrival at the hospital. However wide-spread application of MSUs is limited due to the sheer financial burden of placing a CT scanner in ambulances. From the authors' perspective, with the current given technology, the costs of applying and maintaining CT scanners in all ambulances in the United States likely outweigh the benefits of time saved. There may be an optimal number of specialized MSUs per given region or district that can effectively respond to cases that are screened for stroke syndromes and then deployed; however currently there exists no cost-effective model.

Significant work has also been applied to create a stroke scoring model that is both accurate and easy to use. Based on our review, ACT-FAST, a new scoring system published in 2018 appears to accurately distinguish LVOs and may be of use by paramedics and other EMS providers in their diagnostic criteria.

Several stroke applications have also been recently invented to help with the acute decision-making. Near-infrared spectroscopy could potentially alter the landscape of prehospital stroke evaluation, but its efficacy and large-scale use remain to be validated. A paper by Nogueria *et al*. details the design of an algorithm for EMS providers to quickly identify LVO vs. small vessel stroke and make the correct decision for which hospital to bring the patient. Although this application is theoretically useful, in order for this application to benefit patients it will need to be widely adapted by EMS providers across the country, and also be constantly updated in regard to hospital wait times, traffic, and should include information on how many stroke patients are currently being treated at each hospital. It also remains to be determined how quickly human providers will give decision-making capacity to an algorithm, and how the public will respond to situations where the algorithm did not correctly identify the type of stroke.

The study by Dickson *et al*. demonstrated the utility of an application that allows for the transmittance of

patient information from EMS providers to the stroke and emergency department teams. They found a very significant decrease in the door to needle time of 40 min in a small patient sample. From the authors perspective, applications such as these are likely more readily achievable than MSUs, as they leverage the use of smartphones and technology which are now largely universal.

Conclusion

The prehospital setting is a significant and relatively easy setting for innovation in stroke care, as most clinical decisions are made within the first several hours of symptom onset. Based on our review of prehospital stroke innovations, we believe that there are several significant innovations in prehospital stroke that may positively impact stroke outcomes. However, additional research is needed to further improve on these models and technologies.

Limitations

Authors acknowledge several factors that may have impacted conclusions made in this article. First, in this narrative review, conclusions were drawn in a manner encompassing studies originating for different selected regions of the world such as the United States and Western Europe. However, there is relatively low representation from African, East Europe, and Asian regions. A more global view of prehospital stroke evaluation is needed, but data are limited in the aforementioned constituencies. Second, database reviewed it did not include an exhaustive review of resources outside of electronic national library database. Third, an attempt to illustrate the current contemporary landscape of prehospital approach to stroke care, the authors omitted the review of prior prehospital stroke review papers published at the time of writing article.

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Conflicts of interest

There are no conflicts of interest.

References

1. Vos T, Allen C, Arora M, Barber RM, Bhutta ZA, Brown A, Coggeshall M. Global, regional, and national incidence, prevalence, and years lived with disability for 310 diseases and injuries, 1990-2015: A systematic analysis for the Global Burden of Disease Study 2015. Lancet 2016;388:1545-602.
2. Writing Group Members, Mozaffarian D, Benjamin EJ, Go AS, Arnett DK, Blaha MJ, *et al.* Heart disease and stroke statistics-2016 update: A report from the American Heart Association. Circulation 2016;133:e38-360.
3. Cadilhac DA, Purvis T, Kilkenny MF, Longworth M, Mohr K, Pollack M, *et al.* Evaluation of rural stroke services: Does implementation of coordinators and pathways improve care in rural hospitals? Stroke 2013;44:2848-53.
4. Stroke Unit Trialists' Collaboration. Organised inpatient (stroke unit) care for stroke. Cochrane Database Syst Rev 2007. Art. No.: CD000197. DOI: 10.1002/14651858.CD000197.pub2.
5. Geisler F, Ali SF, Ebinger M, Kunz A, Rozanski M, Waldschmidt C, *et al*. Evaluation of a score for the prehospital distinction between cerebrovascular disease and stroke mimic patients. Int J Stroke. 2018:1747493018806194. doi: 10.1177/1747493018806194
6. Li T, Cushman JT, Shah MN, Kelly AG, Rich DQ, Jones CM, *et al*. Barriers to providing prehospital care to ischemic stroke patients: Predictors and impact on care. Prehosp Disaster Med 2018;33:501-7.
7. Walter S, Zhao H, Easton D, Bil C, Sauer J, Liu Y, *et al.* Air-mobile stroke unit for access to stroke treatment in rural regions. Int J Stroke 2018;13:568-75.
8. Nyberg EM, Cox JR, Kowalski RG, Vela-Duarte D, Schimpf B, Jones WJ, *et al.* Mobile stroke unit reduces time to image acquisition and reporting. AJNR Am J Neuroradiol 2018;39:1293-5.
9. Holodinsky JK, Williamson TS, Demchuk AM, Zhao H, Zhu L, Francis MJ, *et al*. Modeling Stroke Patient Transport for All Patients With Suspected Large-Vessel Occlusion. JAMA Neurol 2018;75:1477-86.
10. Smith SN, Brown PC, Waits KH, Wong JS, Bhatti MS, Toqeer Q, *et al*. Development and evaluation of a user centered mobile telestroke platform. Telemed J E Health 2018. DOI:doi.org/10.1089/tmj.2018.0044.
11. Evenson KR, Foraker RE, Morris DL, Rosamond WD. A comprehensive review of prehospital and in-hospital delay times in acute stroke care. Int J Stroke 2009;4:187-99.
12. Leiva-Salinas C, Jiang B, Wintermark M. Computed tomography, computed tomography angiography, and perfusion computed tomography evaluation of acute ischemic stroke. Neuroimaging Clin N Am 2018;28:565-72.
13. Wendt M, Ebinger M, Kunz A, Rozanski M, Waldschmidt C, Weber JE, *et al.* Improved prehospital triage of patients with stroke in a specialized stroke ambulance: Results of the pre-hospital acute neurological therapy and optimization of medical care in stroke study. Stroke 2015;46:740-5.
14. Pickham D, Valdez A, Demeestere J, Lemmens R, Diaz L, Hopper S, *et al*. Prognostic Value of BEFAST vs. FAST to Identify Stroke in a Prehospital Setting. Prehosp Emerg Care 2018. DOI: 10.1080/10903127.2018.1490837
15. Zhao H, Pesavento L, Coote S, Rodrigues E, Salvaris P, Smith K, *et al.* Ambulance clinical triage for acute stroke treatment: Paramedic triage algorithm for large vessel occlusion. Stroke 2018;49:945-51.
16. Nogueira RG, Silva GS, Lima FO, Yeh YC, Fleming C, Branco D, *et al.* The FAST-ED app: A Smartphone platform for the field triage of patients with stroke. Stroke 2017;48:1278-84.
17. Dickson RL, Sumathipala D, Reeves J. Stop stroke© acute care coordination medical application: A Brief report on postimplementation performance at a primary stroke center. J Stroke Cerebrovasc Dis 2016;25:1275-9.
18. Hidlay DT, McTaggart RA, Baird G, Yaghi S, Hemendinger M, Tung EL, *et al.* Accuracy of smartphone-based evaluation of emergent large vessel occlusion on CTA. Clin Neurol Neurosurg 2018;171:135-8.
19. Terborg C, Gröschel K, Petrovitch A, Ringer T, Schnaudigel S, Witte OW, *et al*. Noninvasive Assessment of Cerebral Perfusion and Oxygenation in Acute Ischemic Stroke by Near-Infrared Spectroscopy. Eur Neurol 2009;62:338-43.
20. Moreau F, Yang R, Nambiar V, Demchuk AM, Dunn JF. Near-infrared measurements of brain oxygenation in stroke. Neurophotonics. 2016;3:031403.
21. Aries MJ, Coumou AD, Elting JW, van der Harst JJ, Kremer BP, Vroomen PC, *et al.* Near infrared spectroscopy for the detection of desaturations in vulnerable ischemic brain tissue: A pilot study at the stroke unit bedside. Stroke 2012;43:1134-6.