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EMS and Acute Stroke Care: Evidence for Policies to Reduce Delays to Definitive Treatments

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Abstract Tremendous advances have altered the management of stroke over the past two decades. In a landmark paper in 1995, intravenous tissue plasminogen activator (TPA) was shown to improve outcomes in stroke patients when compared with the standard treatment at the time. Municipalities around the country created destination plans for their EMS systems to direct stroke patients to an appropriate stroke center and therefore prevent the costly time delays associated with interfacility transports. When properly identified as a stroke by EMS, studies show that EMS prenotification to the hospital leads to faster in-hospital times and in some cases faster treatment times. With such an important role of EMS in stroke care, the importance of proper recognition by EMS became paramount. Stroke identification tools were developed to aid in stroke recognition with varying results. Some systems developed mobile stroke units to bring the emergency department to the patient to expedite TPA administration. Recently, five studies published in 2015 demonstrated the benefit of intra-arterial thrombolysis (IAT) for patients with large-vessel occlusions (LVO). While primary stroke centers are able to provide TPA management, comprehensive stroke centers are the only centers capable of providing intra-arterial interventions. Should IAT become the standard of care, EMS will have a responsibility to adjust its stroke recognition systems to differentiate patients with LVOs who might benefit from intervention at a comprehensive stroke center (CSC) and appropriately bypass a primary stroke center (PSC) for a CSC to provide them the best opportunity to receive this time-sensitive therapy and prevent the significant interfacility transport delays.

Keywords Emergency medical services · Stroke · Triage · Prehospital emergency care · Tissue plasminogen activator

Introduction

Tremendous advances have altered the management of stroke over the past two decades. In 1995, the Stroke Study Group for the National Institute of Neurological Disorders and Stroke published their findings that intravenous tissue plasminogen activator (TPA) could lead to improved outcomes in stroke patients when compared with the standard treatment at the time [1]. This revolution in stroke management spawned other innovations such as the regionalization of stroke care and the creation of primary stroke center (PSC) and comprehensive stroke center (CSC) designations. Municipalities around the country developed protocols with destination plans to direct stroke patients to an appropriate stroke center to provide them the opportunity to be given TPA in a timely manner and prevent the costly time delays associated with interfacility transports. Suddenly, EMS was given the responsibility of transporting patients not to the closest emergency facility but rather the closest facility appropriate for their condition. Stroke was recognized as a time-sensitive condition similar to the likes of ST elevation myocardial infarction (STEMI) and trauma. Despite significant efforts at regionalization and awareness, it is believed that less than 5 % of acute stroke patients receive TPA therapy [2, 3•]. Improving EMS management of stroke can have tremendous impact, with 63.7 % of all stroke patients transported by EMS to the hospital [4].

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Similarly, those patients who utilize EMS are more likely to be experiencing severe strokes and are those who would most likely benefit from more sophisticated treatment modalities. While EMS providers may not be able to individually treat strokes, studies have shown significant benefit with regard to EMS prenotification to hospitals when it comes to stroke. With such large numbers of stroke patients presenting to the hospital with EMS and yet such a small percentage of patients actually receiving TPA, there is plenty of room for improvement when it comes to stroke care.

Twenty years after TPA's approval by the Food and Drug Administration (FDA), five studies published in 2015 demonstrated the benefit of intra-arterial thrombolysis (IAT) for patients with large-vessel occlusions (LVO), a small subset of ischemic stroke patients for whom standard TPA treatment was less beneficial [5–9]. While primary stroke centers are able to provide TPA management, comprehensive stroke centers are the only centers capable of providing intra-arterial interventions. Few if any systems in the USA currently differentiate between PSC and CSC when it comes to EMS transport. Should intra-arterial interventions become the standard of care, EMS will have a responsibility to adjust its stroke recognition systems to delineate whether its stroke patients might benefit from a comprehensive stroke center treatment instead of a primary stroke center treatment. As investigators further define treatment protocols and innovations for subgroups within the population of stroke patients, new EMS protocols will need to be developed to better delineate and triage stroke patients who may further benefit from new treatments.

Stroke Bypass Strategies

Since the approval of TPA as a treatment for acute ischemic strokes in the USA, regions across the country have adopted stroke bypass strategies for EMS to transport stroke patients directly to stroke centers with varying levels of success. Using a citywide stroke system with preference to transporting patients to primary stroke centers, the city of Chicago saw its use of TPA more than double. During their time period, they also saw a statistically significant increase in the use of EMS prenotification from 65.5 to 76.5 % ($p = 0.001$) with a significant decrease in the onset of symptoms to treatment time from 171.7 to 145.7 min ($p = 0.03$) [10]. Another example of a successful urban stroke bypass strategy is Los Angeles (LA) County. Sanossian et al. investigated the effect of an EMS routing policy for stroke patients in LA County. They found that when comparing before and after implementation of the routing policy, 10 % of stroke patients prior to the policy were transported to a PSC whereas after the policy 91 % of patients were transported to such a facility ($p < 0.001$). In their study, 29 % of CVA patients received TPA before rerouting, whereas 42 % received TPA after rerouting ($p < 0.001$). Scene-to-ED door time actually decreased when comparing these two groups, with the prediversion group having an average time of 34.5 min and the diversion group having an average time of 33.5 min ($p = 0.045$) [11•]. Atsumi et al. published similar findings when evaluating the success of an EMS routing protocol in Kawasaki City, Japan. While their study did not compare pre-bypass to post-bypass times, it compared transport statistics in the years after implementation of the policy. Similar to the LA County results, they showed that the ambulance call-to-ED door time decreased from 37.5 ± 12.5 to 33.9 ± 11.7 min ($p = 0.000$) [12]. While the results in LA County and Chicago were extremely compelling in showing significant improvement in TPA rates, they did not address the actual issue of hospital bypass, with no data to demonstrate how many patients bypassed non-PSCs to be transported to a PSC. In fact, both the LA and Kawasaki studies showed a slight reduction in the scene-to-ED time between the prediversion and diversion periods. In a highly populated urban setting, the establishment of a regional stroke system can lead to a significant increase in the rate of TPA administration and reduce the time from onset of symptoms to TPA treatment.

While a regional stroke system in an urban setting may increase rates of TPA administration, this trend may not apply in all settings. This issue was addressed by Asimos et al., who specifically looked at rates of hospital bypass after introduction of a stroke triage plan in North Carolina. They showed no difference in bypass rates to stroke centers when comparing before and after introduction of a stroke triage and destination plan. They also showed no significant differences in mean transport and on-scene times when looking at on-scene times of less than or equal to 10 min or greater than 10 min [13]. In that same study, they showed that when EMS did bypass a community hospital for a stroke center, it added between 12 and 14 min to the average transport time without bypass. It should be noted that North Carolina is a mostly rural state with geographically distant medical centers. The distance between medical centers did in fact play a role in the ability of EMS to bypass. In cases where a community hospital was the closest hospital, they found that up to a fourth of patients would not have been eligible for bypass because the associated transport times of the bypass exceeded the time constraints they set out in the stroke triage and destination plan. While regional stroke bypass strategies have shown to be beneficial in some areas, it is important to recognize the hurdles other areas face to better standardize stroke treatment across the country.

EMS Prenotification

While stroke bypass strategies by EMS have shown varying results, there are a host of other strategies that have reaped tremendous benefits in terms of time savings and increased number of patients receiving appropriate therapy including

EMS prenotification. In the confines of stroke management, EMS prenotification has shown tremendous benefits in reducing in-hospital times. In one study by Abdullah et al., advance notification of arrival by EMS led to a significant reduction in time to CT and almost double the number of patients treated with thrombolysis [14]. There have been many other studies which have also shown significant reductions in door-to-CT times with patients arriving with EMS prenotification [15, 16]. The benefits of prenotification have been shown in other similar time-sensitive conditions such as STEMI and trauma management, and therefore, it is not surprising that it would benefit stroke patients as well. Should EMS be successful in recognizing stroke, the use of prenotification has been shown to reduce time to evaluation and, in some studies at least, reduced door-to-needle times.

Interfacility Transfer Delays

While prenotification of time-sensitive conditions has shown significant benefit, transporting patients to facilities incapable of managing those conditions can lead to costly time delays especially with time-sensitive conditions. With the likely introduction of intra-arterial thrombolysis into the standard management of LVO strokes, there is greater concern that the delays in transfer between PSC and CSC facilities will prohibit some patients from receiving treatment. One study that looked at interfacility transports found that the average distance between facilities was 14.7 miles, yet the median transfer time was 104 min. Similarly, when looking at why patients did not receive intra-arterial therapy for stroke, they found that the elapsed treatment time window secondary to transfer delay was the second most common reason making up 14 % of patients excluded from IAT [17]. Contrast this to the Asimos study above in which the average time it took EMS to bypass a community hospital and transfer to a PSC was only 12–14 min [13]. While this does not address the time it might take to transfer patients directly to a CSC instead of a PSC, it does suggest that the time spent by EMS bypassing a PSC will likely be a lot shorter than the time it takes for interfacility transports.

Stroke Recognition by EMS Providers

While prenotification and community hospital bypass may be extremely helpful in the management of stroke, it requires EMS to accurately identify stroke patients. In the USA, the most commonly used screening tools for stroke include the Cincinnati Prehospital Stroke Scale (CPSS) and the Los Angeles Prehospital Stroke Screen (LAPSS). In order to have a successful hospital bypass system, EMS will need a tool which is both highly sensitive and specific at diagnosing stroke. Several studies have evaluated the sensitivity and specificity of the different prehospital stroke scales (Table 1). Studnek et al. evaluated the validity of the CPSS. They found a sensitivity for the CPSS of 79 % (95 % CI 72.3–84.5 %) with a specificity of 23.9 % (95 % CI 18.7–30 %). By combining the benefits of both the LAPSS and CPSS, they proposed using a new scale they called the Medic Prehospital Assessment for Code Stroke (Med PACS) which demonstrated a sensitivity of 74.2 % (95 % CI 0.67.2–80.2 %) and a specificity of 32.6 % (95 % CI 26.7–39.1 %). This scale added gaze preference and motor function of the legs to the standard physical exam included in the CPSS. When comparing the two stroke screens, they found a statistically significant higher sensitivity of CPSS and a statistically significant higher specificity using Med PACS [19]. Oostema et al. also evaluated the effectiveness of diagnosing stroke using the CPSS. They found a sensitivity of 73.5 % (95 % CI 67.7–78.7) [15]. In a study conducted by Asimos et al. looking at stroke recognition in North Carolina, they found similar sensitivity with a slightly higher specificity of CPSS with a sensitivity of 80 % (95 % CI 77–83 %) and a specificity of 48 % (95 % CI 44–52 %). When evaluating the LAPSS, they found a sensitivity of 74 % (95 % CI 71–77 %) and a specificity of 48 % (95 % CI 43–53 %) [18]. These low specificities are concerning in any system with a bypass protocol, as it means longer transport times for non-stroke patients. Over triage also stresses stroke centers, with higher volumes and greater utilization of their resources for non-stroke patients. In rural settings, bypass also leads to longer turnaround times for ambulances leaving regions without needed EMS coverage. While some over triage is expected to allow greater numbers of patients access to advanced stroke care, no clear guideline has been established as to the degree of over triage that should be allowed. In order to improve EMS recognition of stroke, it is important to understand what features of stroke EMS providers were missing to improve both the sensitivity and specificity of their screens.

When reviewing the literature on missed strokes by EMS, severe stroke presentations, lack of documentation of a stroke exam, and nonmotor signs of stroke appear to cause the greatest difficulties. A study published by Gropen et al. found that EMS had the lowest sensitivities in stroke diagnosis in both the lower and higher NIHSS scores. They also found that EMS had greatest difficulty in diagnosing stroke when nonmotor signs predominated including aphasia and neglect [22]. In another study, the most common EMS impressions on missed strokes included generalized weakness, altered mental status, or dizziness. This study also showed a strong relationship between CPSS documentation and sensitivity of stroke. In half of their missed-stroke cases, there was documented unilateral weakness in the ED and in only 30 % of those cases did EMS even document a CPSS [15]. Increased documentation of CPSS and using stroke scales which include nonmotor signs may lead to greater sensitivity of stroke diagnosis.

Table 1 Sensitivity and specificity of stroke scales

Study authors	Screening tool	Sensitivity	Specificity	Sample size	Study type
Standard stroke scales					
Asimos et al. [18]	CPSS	80 % (95 % CI 77–83)	48 % (95 % CI 44–52)	1217	Retrospective
Oostema et al. [15]	CPSS	73.5 % (95 % CI 68–79)		441	Observational
Studnek et al. [19]	CPSS	79 % (95 % CI 72–85)	23.9 % (95 % CI 19–30)	416	Retrospective
Asimos et al. [18]	LAPSS	74 % (95 % CI 71–77)	48 % (95 % CI 43–53)	1225	Retrospective
Studnek et al. [19]	MED PACS	74.2 % (95 % CI 67–80)	32.6 % (95 % CI 27–39)	416	Retrospective
Proposed stroke scales for large-vessel occlusions					
Perez de la Ossa et al. [20••]	RACE (score of ≥5 for LVO)	85 %	68 %	357	Prospective
Katz et al. [21]	CPSSS (score ≥2 for LVO)	83 %	40 %	650	Retrospective

Sensitivity and specificity calculations were made based on comparison to the hospital diagnoses of the patients

With current stroke assessment scales not providing sufficient sensitivity and specificity of stroke and also not differentiating strokes with higher severity, efforts are currently underway to develop new EMS tools for stroke assessment. With the potential need for patients with more severe strokes to bypass PSC for CSC care, it is imperative that as new prehospital stroke scales are developed, they accurately distinguish between small strokes and strokes which may involve an LVO. In the simplest tool for prehospital providers to evaluate for LVO, one study looked at severe hemiplegia as a marker of stroke severity to suggest patients who may benefit from IAT. While this was a small pilot study involving only 45 patients, 26.7 % of patients had an LVO treated with thrombectomy, with a total of 46.7 % patients receiving an acute treatment [23]. Other investigators have modified the Cincinnati Prehospital Stroke Scale to better distinguish higher severity strokes. This new Cincinnati Prehospital Stroke Severity Scale (CPSSS) includes gaze, level of consciousness, and motor exam in its score. When evaluating for severe strokes, they found an 89 % sensitivity, a 73 % specificity, a positive likelihood ratio of 3.3, and a negative likelihood ratio of 0.15. When only looking at LVO, they found an 83 % sensitivity, a 40 % specificity, a positive likelihood ratio of 1.4, and a negative likelihood ratio of 0.4 [21]. The Rapid Arterial oCclusion Evaluation (RACE) scale was developed similarly to these other tools to help EMS establish stroke severity and better establish possible cases of LVOs. Five areas of the exam were included when developing the RACE scale, including facial palsy, arm and leg motor function, gaze, aphasia, and agnosia. This scale showed an impressive correlation of 93 % between its score and the NIH Stroke Scale (NIHSS) score ($p < 0.001$). When looking at its detection of LVO, it found a sensitivity of 85 %, a specificity of 68 %, a positive predictive value of 42 %, and a negative predictive value of 94 %. When comparing these results with the NIHSS, the investigators found an NIHSS of greater than or equal to 11 had a sensitivity of 88 %, a specificity of 72 %, and an overall accuracy of 76 % [20••]. These new screening tools may help EMS distinguish higher severity strokes to better triage stroke patients to the appropriate facility based on the severity of their stroke.

Mobile Stroke Units

Some jurisdictions have gone a step further in stroke management and brought the hospital to the scene to provide patients with faster TPA administration. Over the past decade, there have been tremendous efforts to expedite TPA administration within the hospital. In Berlin, Germany, a specialized ambulance was created in order to bring hospital resources to the scene to expedite stroke care. This ambulance, called the Stroke Emergency Mobile (STEMO), is staffed with a neurologist, a paramedic, and a radiology technician and includes a CT scanner. During their study period from 2011 to 2013, the use of STEMO increased the number of TPA treatments within the first hour from 4.9 to 31.0 % ($p < 0.01$) [24, 25]. This concept has since been replicated in Cleveland with the development of a Mobile Stroke Unit (MSTU) and in Houston with the Mobile Stroke Unit [26, 27]. In Cleveland, patients with an NIHSS greater than or equal to 8 are triaged to a CSC for possible IAT. While this model will not work in every region, its success demonstrates that early appropriate stroke care can have significant impact on patient morbidity and mortality, and every effort should be made to get patients to the most appropriate facility.

Conclusion

EMS has an important role in the regionalization of stroke care. They can often minimize prolonged interfacility transfer times by transporting appropriate severe stroke patients to a CSC first. While the development of PSCs across the country has allowed for greater TPA access to patients, it has also led to fewer patients presenting directly to CSCs. In one Houston CSC, they found during the period of 2005 to 2011 a significant decline from 33 to 22 % of patients presenting with LVO to their facility directly. Grotta et al. go on to suggest that with current advances in stroke management, EMS should institute a severity-adjusted EMS triage algorithm to get patients with LVO directly to a CSC, in the same way EMS already transports trauma patients based on severity to different level trauma centers [3•]. In another paper, Grotta et al. suggest that even community hospitals without CTA/MR access need to utilize a stroke severity triage system to allow patients with LVO the possibility of IAT, by arranging for interfacility transport of patients with an NIHSS of greater than or equal to 12 [28]. With newer stroke scales that better distinguish stroke severity, EMS finds itself at the forefront of IAT management, serving as a primary gatekeeper for patients to possible IAT. While further research may be necessary to determine what EMS screening tool allows for the greatest sensitivity and specificity for severe stroke recognition, EMS must begin to adjust its stroke destination triage plans to distinguish between minor strokes and possible LVOs to get them to CSCs faster.

Compliance with Ethical Standards

Conflict of Interest Drs Grover, Morales, and Brice all declare no conflicts of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by the authors.

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