Stroke

CLINICAL AND POPULATION SCIENCES

Emergency Medical Services Compliance With Prehospital Stroke Quality Metrics Is Associated With Faster Stroke Evaluation and Treatment

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BACKGROUND: Emergency medical services (EMS) is an important link in the stroke chain of recovery. Various prehospital quality metrics have been proposed for prehospital stroke care, but their individual impact is uncertain. We sought to measure associations between EMS quality metrics and downstream stroke care.

METHODS: This is a retrospective analysis of a cohort of EMS-transported stroke patients assembled through a linkage between Michigan's EMS and stroke registries. We used multivariable regression to quantify the independent associations between EMS quality metric compliance (dispatch within 90 seconds of 911 call, prehospital stroke screen documentation [Prehospital stroke scale], glucose check, last known well time, maintenance of scene times ≤15 minutes, hospital prenotification, and intravenous line placement) and shorter door-to-CT times (door-to-CT ≤25), accounting for EMS recognition, age, sex, race, stroke subtype, severity, and duration of symptoms. We then developed a simple EMS quality score based on metrics associated with early CT and examined its associations with hospital stroke evaluation times, treatment, and patient outcomes.

RESULTS: Five thousand seven hundred seven EMS-transported stroke cases were linked to prehospital records from January 2018 through June 2019. In multivariable analysis, prehospital stroke scale documentation (adjusted odds ratio, 1.4 [1.2–1.6]), glucose check (1.3 [1.1–1.6]), on-scene time ≤15 minutes (1.6 [1.4–1.9]), hospital prenotification ([2.0 [1.4–2.9]), and intravenous line placement (1.8 [1.5–2.1]) were independently associated with a door-to-CT ≤25 minutes. A 5-point quality score (1 point for each element) was therefore developed. In multivariable analysis, a 1-point higher EMS quality score was associated with a shorter time from EMS contact to CT (−9.2 [−10.6 to −7.8] minutes; P<0.001) and thrombolysis (−4.3 [−6.4 to −2.2] minutes; P<0.001), and higher odds of discharge to home (adjusted odds ratio, 1.1 [1.0–1.2]; P=0.002).

CONCLUSIONS: Five EMS actions recommended by national guidelines were associated with rapid CT imaging. A simple quality score derived from these measures was also associated with faster stroke evaluation, greater odds of reperfusion treatment, and discharge to home.

GRAPHIC ABSTRACT: A graphic abstract is available for this article.

Key Words: data linkage ■ emergency medical services ■ quality of health care ■ registries ■ reperfusion

Acute stroke is a medical emergency that is responsible for a substantial burden of morbidity and mortality.[1] Although the arsenal of effective treatments for ischemic stroke has expanded in recent years, the benefit of reperfusion therapies has decreased steadily over time.[2,3] Therefore, the central goal of emergency systems is early identification of stroke cases and rapid transport to hospitals capable of delivering appropriate treatment.[4]

As the first point of contact for many patients with stroke accessing the health care system,[5] emergency dispatchers and on-scene EMS providers have the earliest opportunity to identify stroke symptoms, direct

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Nonstandard Abbreviations and Acronyms

DTCT	door-to-CT
DTN	door-to-needle
EVT	endovascular therapy
FMC	first medical contact
LKW	last known well
MI-EMSIS	Michigan EMS Information System
PSS	prehospital stroke scale

patients to appropriate hospitals, and expedite care through prehospital activation of stroke teams. Compared with patients with stroke who arrive by private vehicle, EMS-transported stroke patients arrive earlier,[6,7] receive diagnostic tests faster,[6,7] and are treated more often[8] and more rapidly[7,9] with reperfusion therapies. There are also significant associations between EMS transport and favorable hemorrhagic stroke outcomes, including earlier treatment[10] and lower mortality.[11]

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Given the importance of EMS within stroke systems of care and the dramatic achievements of systematic in-hospital quality improvement efforts on acute stroke care,[12] there is increasing interest in optimizing prehospital stroke care. Numerous recommendations for EMS care have been articulated in American Heart Association/American Stroke Association national stroke guidelines,[4,13–15] directed toward accurate recognition of stroke (glucose check, utilization of a validated prehospital stroke screen), improving the efficiency of transport (on-scene time goals, obtaining last known well [LKW] times to communicate to hospital personnel), and activating in-hospital stroke teams through prehospital notification of impending arrival (Table 1). Many of these recommendations have been incorporated into EMS training and transport protocols, and EMS quality improvement programs are increasingly looking to monitor metrics based on these metrics.[18] To date, the National EMS Quality Alliance has adopted only 1 stroke quality measure: prehospital stroke screen performance.[16] However, the American Heart Association's Mission: Lifeline program has added stroke screen performance, prenotification, glucose check documentation, and LKW-time documentation to its EMS recognition measures.[17] Nevertheless, apart from prenotification,[8,19] studies linking performance of EMS quality indicators to patient outcomes are lacking, a shortcoming identified as a top priority for the development of evidence-based EMS quality metrics by the Prehospital Guidelines Consortium.[20] To address this gap, we utilized a statewide cohort of EMS-transported acute stroke cases (ischemic and hemorrhagic) in Michigan to examine associations between compliance with 7 recommended prehospital quality metrics and the speed of in-hospital stroke evaluation, treatment, and patient outcomes. Our objective was to develop a simple summary measure of EMS stroke care quality and to determine whether it correlates with ED performance on stroke evaluation and treatment metrics and in-hospital patient outcomes.

METHODS

This is a retrospective analysis of a cohort of EMS-transported stroke cases obtained from a previous match of individual patient records Michigan's Coverdell Acute Stroke Registry (38/129 hospitals in Michigan, 29.4%) to the Michigan's EMS Information System (MI-EMSIS)[21,22] over 18 months (January 2018 through June 2019). The details of the matching process and outcomes have been published previously.[23] Briefly, a probabilistic match using LinkPlus software (Centers for Disease Control and Prevention) linked 5985/8828 stroke registry records (67%) to EMS records in MI-EMSIS using a combination of variables including receiving hospital, patient age, date of birth, sex, and date of service.[24] Cases without a stroke diagnosis or documentation of a CT within 0 to 6 hours of arrival

Table 1. Candidate EMS Quality Indicators for Prehospital Stroke Care

Indicator	Definition	Endorsement as quality metric
9–1 to 1 to dispatch <90 seconds	Difference between 9–1 and 1 call time and time EMS deployed	
Prehospital stroke scale documentation	Documentation of any validated prehospital stroke scale	NEMSQA,* AHA Mission: Lifeline†
Glucose check documented	Documentation of the result of a point-of-care glucose test	AHA Mission: Lifeline†
LKW documentation	Documentation of the time a patient was last known to be at their neurological baseline	AHA Mission: Lifeline†
On-scene time ≤15 min	Difference in minutes between EMS arrival on-scene and time left scene to begin transport	
Hospital pre-notification	Documentation indicating activation of a stroke alert	AHA Mission: Lifeline†
IV placed	Documentation of IV placement	

All metrics were derived from EMS records in MI-EMSIS. AHA indicates American Heart Association; EMS, emergency medical services; IV, intravenous line; LKW, last known well; and MI-EMSIS, Michigan EMS information system.

*National EMS quality alliance.[16]

†AHA Mission: Lifeline.[17]

(n=278) were excluded from analysis. The data that support the findings of this study are available from the corresponding author upon reasonable request.

Exposures and Covariates of Interest

The primary exposures of interest were 7 binary prehospital stroke quality metrics derived from national guidelines that are also incorporated into the State of Michigan EMS stroke protocol.[14,25,26] These included documentation of (1) time from 911 call to dispatch <90 seconds, (2) glucose check, (3) use of a prehospital stroke screen, (4) LKW time documentation, (5) on-scene time ≤15 minutes, (6) hospital prenotification, and (7) intravenous line placement. Hospital prenotification for this analysis was derived from EMS records since our focus was on demonstrating the value of prehospital data, although documentation rates were notably lower in EMS records than the stroke registry (8% versus 60%). Important potential confounders identified in previous analysis[27] included patient age, sex, race, stroke type (ischemic stroke, transient ischemic attack, intracerebral hemorrhage), stroke severity (as measured by the NIHSS), EMS stroke recognition (an EMS primary or secondary impression of stroke or TIA), and time from LKW to hospital arrival. Patient and disease characteristics were derived from stroke registry data while EMS performance was obtained from EMS records.

Outcome Measures

Achievement of early brain imaging (defined as a door-to-CT [DTCT] time ≤25 minutes) served as the primary outcome since it is relevant to both ischemic and hemorrhagic stroke patients and may plausibly be influenced by optimal EMS care. Time to CT was also evaluated as a continuous outcome measure both from arrival at the hospital door and from the time of first medical contact (FMC) on-scene by EMS providers. We then examined treatment with thrombolysis or endovascular therapy (EVT) among patients with ischemic stroke. For patients with ischemic stroke treated with thrombolysis, we evaluated time to treatment both as a binary outcome (achievement of a door-to-needle [DTN] time of time ≤45 minutes) as well as a continuous variable from hospital door and from FMC to delivery of thrombolysis. Finally, we assessed patient-centered outcomes for all patients with stroke including hospital disposition (discharged to home versus other) and in-hospital mortality (death in-hospital or transfer to hospice care versus alive at discharge).

Statistical Analysis

We first assessed collinearity between quality indicators by calculating bivariate phi correlation coefficients between all metrics.[28] Next, bivariate associations between each candidate quality metric and the primary outcome (DTCT ≤25 minutes) were estimated using logistic regression, accounting for clustering by including a random effect for unique EMS agency and hospital pairs.[27,29] Following this, random-effects multivariable logistic regression models were constructed to measure the independent associations between each quality metric and DTCT ≤25 minutes while accounting for patient-level characteristics (age, sex, race, stroke subtype, NIHSS, EMS recognition of stroke, time from LKW to hospital arrival). Categorical variables for race, NIHSS, and time from LKW to hospital variables were created with a dummy variable for missing documentation. Finally, a random-effects multivariable logistic regression model was constructed that included all quality metrics with a significant independent relationship with early CT.

After identifying the quality metrics that were independently associated with early CT, we developed an EMS quality score based on the numerical sum of EMS quality metrics documented. To assess the potential value of this summary score, we performed random-effects logistic regression to estimate the association between the linear continuous score (range, 0–5) and the primary and secondary outcomes, including DTCT ≤25 minutes among all patients, EVT and thrombolysis treatment among acute ischemic strokes, thrombolysis delivery ≤45 minutes of arrival for cases treated with thrombolysis, and discharge to home and in-hospital mortality among all cases. We also performed random-effects linear regression models to examine the associations between higher EMS quality scores and all continuous outcomes, including time to CT (for all cases) and time to drug delivery among cases treated with thrombolysis measured both from the time of first EMS contact and from the time of hospital arrival. All models were adjusted for the patient-level characteristics above (excluding stroke subtype for models related to ischemic stroke treatment). Model fit was assessed by plotting observed versus predicted probabilities of early CT and plotting cluster-specific probabilities to ensure normality.

We also conducted several sensitivity analyses. Because the 911 to dispatch metric could not be calculated for many cases, we examined the relationship between compliance and early CT when unknown values were assumed to be all compliant or noncompliant. To ensure that the quality score performed well among early-presenting stroke patients, we also conducted sensitivity analyses by rerunning the regression model only among cases who presented within 6 hours of LKW. Finally, to address the large difference between prenotification documentation in EMS records versus hospital records, we computed EMS quality scores replacing the EMS-documented prenotification variable with registry-documented prenotification and reran models for each of the outcomes using this updated score.

These results were reported according to the reporting of studies conducted using Observational Routinely collected Data guideline.[30] All analyses were conducted using Stata (Version 15). This quality improvement analysis of deidentified data received an exempt determination from the Michigan Department of Health and Human Services institutional review board and, thus, informed consent was not required.

RESULTS

Between January 2018 and July 2019, 5707 EMS-transported acute stroke cases met inclusion criteria. Characteristics of the study population are presented in Table 2. The population median age was 74 with a slight female predominance (52%). Most cases were ischemic strokes or TIA (83%), with 14% receiving a diagnosis of ICH and 3% SAH. Median DTCT time was 21 minutes (10–54), 959 (16%) received thrombolysis, 256 (5%) cases received EVT, 1979 (35%) were discharged home, and 888 (16%) died or were discharged to hospice.

Table 2. Characteristics of All EMS-Transported, Confirmed Stroke Cases Linked to an MI-EMSIS Record Between January 2018 and June 2019

Characteristic	All patients N=5707 (%)
Age category	
<60	1081 (18.9)
60–69	1197 (21)
70–79	1383 (24.2)
80–89	1436 (25.2)
>89	610 (10.7)
Female patients	2971 (52.1)
Race	
White	4147 (72.7)
Black	1232 (21.6)
Other/missing	328 (5.8)
Stroke type	
IS/TIA/stroke NOS	4732 (82.9)
SAH	169 (3.0)
ICH	806 (14.1)
LVO*	182 (15.9)*
NIHSS	
0–5	2609 (45.7)
6–11	1093 (19.2)
12–20	808 (14.2)
>20	532 (9.3)
Missing	665 (11.7)
Onset to door, min	
0–120	1894 (33.2)
121–360	885 (15.5)
136–720	645 (11.3)
>720	1344 (23.6)
Missing	939 (16.5)
CT performed	5707 (100)
DTCT ≤25 min	3214 (56.3)
Median DTCT (2nd, 3rd quartile)	21 (10–54)
FMC to CT (2nd, 3rd quartile)	54 (38–90)
Thrombolysis	959 (16.8)
DTN ≤45	469 (49.0)
Median DTN (2nd, 3rd quartile)	46 (36–64)
FMC to needle time (2nd, 3rd quartile)	76 (62–95)
EVT	295 (5.2)

DTCT indicates door-to-CT; DTN, door-to-needle; EMS, emergency medical services; EVT, endovascular therapy; FMC, first medical contact (time of EMS arrival on scene); ICH, intracranial hemorrhage; IS, ischemic stroke; LVO, large vessel occlusion; NIHSS, National Institutes of Health Stroke Scale; NOS, not otherwise specified; SAH, subarachnoid hemorrhage; and TIA, transient ischemic attack.

*Out of 1148 cases with documentation of LVO status.

In unadjusted analysis, 6 of the 7 candidate prehospital stroke quality metrics were significantly associated with DTCT ≤25 minutes following hospital arrival. These associations remained significant following adjustment for patient-level covariates and clustering by agency-hospital pairs (Table 3). In the best-case and worst-case sensitivity analysis for the 911 to dispatch metric, neither assuming all missing cases were compliant (OR, 1.0 [0.8–1.2]) nor assuming noncompliance (OR, 1.1 [0.6–2.1]) resulted in a significant association with early CT, and so it was dropped from further consideration. When all 6 of the remaining quality metrics were included in the same multivariable model, all of them remained significantly associated with early CT except for LKW documentation, which was dropped from the final model. The remaining 5 quality metrics were used to assign an overall EMS quality score to each case in the database (1 point for each metric performed; Figure 1).

Graphs demonstrating the relationships between the EMS quality score with time to imaging and thrombolysis delivery are presented in Figure 2. Generally, there were negative associations between higher scores and each time interval. This trend was similar in slope for time to CT whether measured from time of hospital arrival (DTCT time) or from time of FMC. The relationship between higher EMS quality scores and DTCT appeared to plateau around a score of 3. In contrast, DTN times differed less dramatically across EMS quality scores, but the trend was more linear. There was substantial variability across agency-hospital pairs in DTCT (median, 22 [IQR, 16–39]) and DTN times (median, 59 [39–49]; Figure S1).

Table 3. Unadjusted and Adjusted Associations Between Documentation of Candidate Quality Metrics and Achievement of a DTCT Time of ≤25 Minutes

Quality metric	Documentation present N=5707 (%)	Unadjusted	DTCT ≤25 min Adjusted for confounders*	Fully adjusted†
911 call to dispatch <90 s	2989 (98.7)‡	1.1 (0.6–2.1)	Dropped	Dropped
PSS documented§‖	3138 (55.0)	3.6 (3.2–4.1)¶	1.5 (1.3–1.7)¶	1.4 (1.2–1.6)¶
Glucose check§	4707 (82.5)	2.0 (1.7–2.4)¶	1.4 (1.2–1.7)¶	1.3 (1.1–1.6)¶
LKW documented§	1374 (24.1)	3.7 (3.1–4.3)¶	1.3 (1.1–1.6)¶	Dropped
On-scene ≤15 min	2827 (49.5)	2.3 (2.0–2.5)¶	1.6 (1.4–1.8)¶	1.6 (1.4–1.9)¶
Hospital pre-notification (stroke alert)§	434 (7.6)	6.3 (4.7–8.5)¶	2.2 (1.6–3.2)¶	2.0 (1.4–2.9)¶
IV placement	4022 (70.1)	2.5 (2.2–2.9)¶	1.8 (1.5–2.1)¶	1.8 (1.5–2.1)¶

AHA indicates American Heart Association; CT, computed tomography; DTCT, door-to-CT; EMS, emergency medical services; IV, intravenous line; LKW, last known well; NIHSS, National Institutes of Health Stroke Scale; and PSS, prehospital stroke scale.

*Adjusted for age, sex, race, EMS recognition of stroke, stroke subtype, NIHSS, time from last known well.

†Adjusted for all other quality metrics in addition to age, sex, race, EMS recognition of stroke, stroke subtype, NIHSS, time from last known well.

‡Of 3029 cases with documentation of both 911 and dispatch time.

§AHA mission: lifeline EMS recognition measures for stroke.

‖National EMS Quality Alliance-endorsed quality measures.

¶Odds ratios were statistically significant (P<0.05). All models account for clustering by unique agency-hospital pairs.

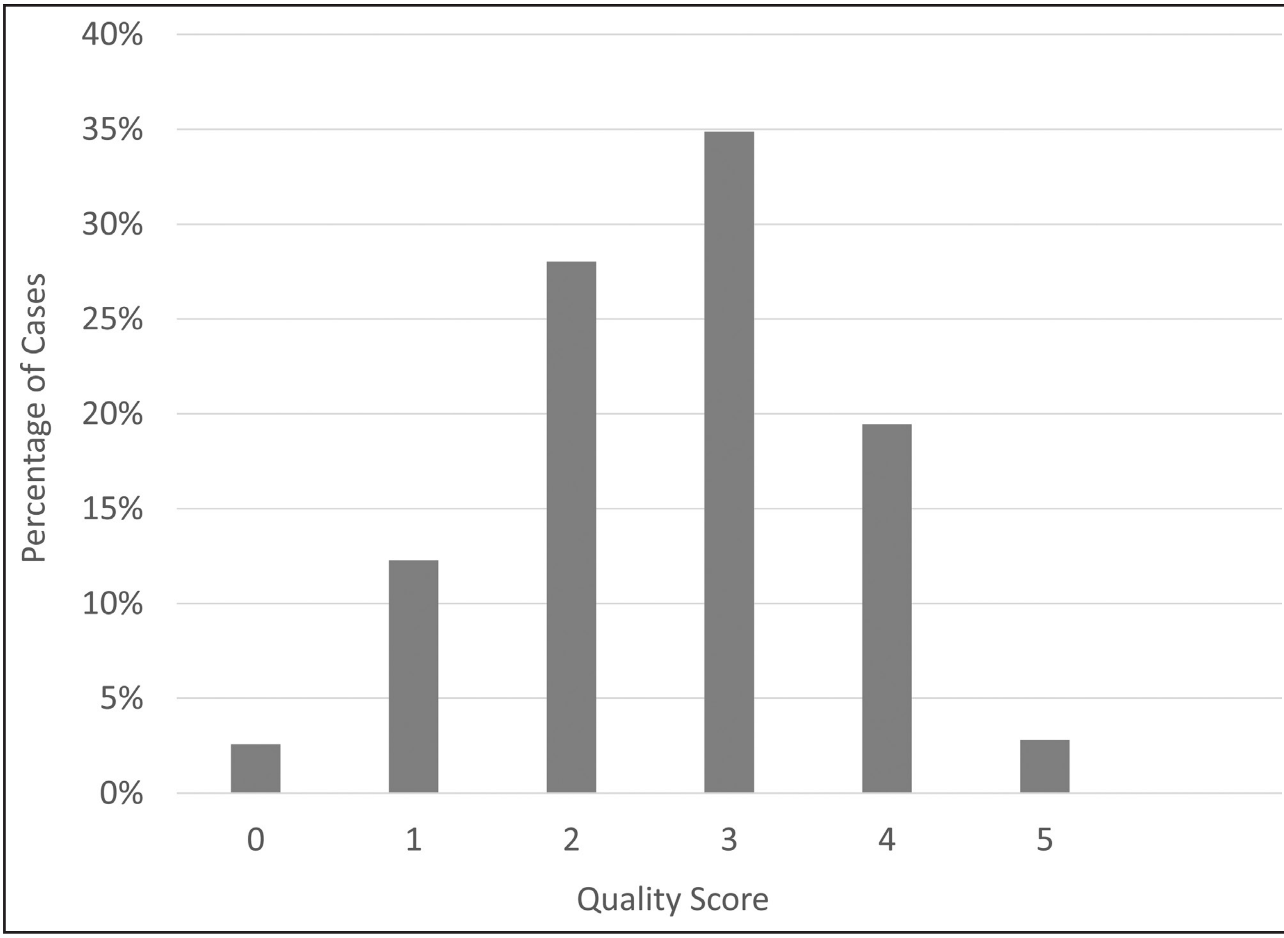

Figure 1. Distribution of summary emergency medical services (EMS) quality scores.
DTCT indicates door-to-CT time; and DTNT, door-to-needle time

The results of multivariable regression models to assess associations between the summary EMS quality score and each outcome are presented in Table 4. In the fully adjusted model, a 1-unit higher EMS quality score was associated with 50% higher odds of achieving an early CT. Plots of observed versus predicted probability of early CT demonstrated acceptable model fit (Figure S2). Sensitivity analysis among 2779 patients who presented within 6 hours of LKW yielded similar results (adjusted odds ratio, 1.4 [1.3–1.6]; P<0.001), and EMS performance scores recalculated using stroke registry documentation of prenotification in place of EMS documentation performed similarly to the EMS-derived scores in predicting all outcomes (Table S2). Positive associations were also observed between the quality score and the odds of thrombolysis treatment (adjusted odds ratio, 1.1 [1.0–1.2]) and EVT treatment (1.3 [1.1–1.5]) among patients with ischemic stroke/TIA. Finally, cases with higher EMS quality scores had higher odds of discharge to home compared with other dispositions (adjusted odds ratio, 1.1 [1.0–1.2] per unit increase in score), although there was no difference in mortality (1.0 [0.9–1.1]).

In adjusted linear models, each additional quality score point was associated with a 7-minute (95% CI, 6–8) faster DTCT time and a 9-minute (95% CI, 8–11) faster time from FMC to CT. Higher EMS quality scores also demonstrated associations with shorter treatment times (2-minute [0–4] faster DTN and 4-minute [2–6] faster FMC to needle time for each additional point).

Intraclass correlation coefficients (ICCs) indicated that group-level effects accounted for little variation in thrombolysis delivery, patient mortality, and discharge to home status (range, 0.1%–3.2%). Group-level effects accounted for a more moderate degree of the variation in DTCT and DTN times (ICC, 4.7–11.9) and a substantial portion of the variation in EVT treatment (44.5%; Table S3).

DISCUSSION

While the important role EMS plays within stroke systems of care is well recognized,[31] and guidelines have established a variety of expectations for prehospital stroke care,[4,14] it is unclear which specific actions performed by EMS positively impact stroke treatment following

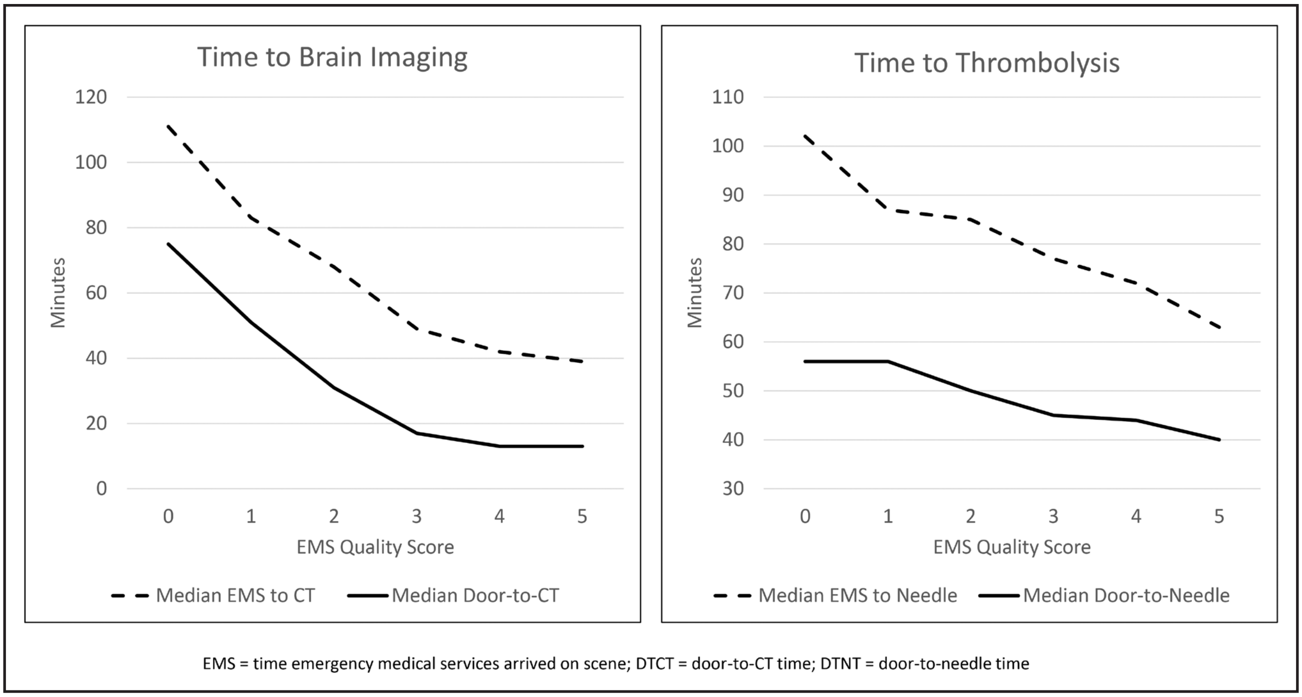

Figure 2. Median time from first emergency medical services (EMS) contact (arrival on scene) or hospital arrival to (A) computed tomography (CT) performance and (B) thrombolytic bolus (needle time) by EMS quality score.

hospital arrival. We present an analysis that leverages a recent linkage between a statewide acute stroke registry and EMS information system to examine associations between EMS quality metrics and downstream stroke care. We identified 5 metrics that were positively and independently associated with early CT acquisition and derived a simple summary score that was strongly correlated with faster brain imaging and faster delivery of thrombolysis to patients with acute ischemic stroke.

To justify their use as quality measures, potential quality indicators should be demonstrably associated with important care processes and patient outcomes.[20,32] In the case of EMS stroke care, analyses linking specific EMS actions to downstream care have been sparse. Previous studies have documented associations between prenotification and faster stroke care[19,33,34] as well as lower mortality.[35] Prehospital stroke scale use has been associated with stroke recognition,[36] which also predicts early CT.[37] Our analysis confirms independent associations between both of these measures and early CT acquisition, regardless of the source of its documentation (EMS versus stroke registry). Additionally, we identified novel independent associations between EMS glucose check, LKW documentation, shorter on-scene times, and prehospital intravenous line placement and early CT in the ED. The mechanisms by which these actions facilitate faster care are not entirely discernable from this observational study, but we presume that additional history gathering and preparation by EMS (such as intravenous line placement) reduces the time needed to complete stroke evaluations following ED arrival. Our findings lend support to current recommendations for prehospital stroke[14,26,38] as well as to the value of stroke scale documentation, currently endorsed as a quality measure by the National EMS Quality Alliance,[16] and the 4 performance measures utilized by the American Heart Association Mission: lifeline EMS recognition program (stroke scale documentation, prenotification, LKW documentation, and glucose check).[17]

EMS compliance with individual quality metrics has been demonstrated to be inconsistent[39] and may be influenced by a variety of patient-level and system-level factors.[27] Therefore, a method to assess the overall quality of stroke-related care provided in the prehospital setting is desirable for benchmarking and monitoring quality improvement interventions. We demonstrate that a simple summary score based on the 5 metrics predictive of faster CT times is consistently associated with several favorable outcomes, including faster CT acquisition, greater likelihood of reperfusion therapy treatment for patients with ischemic stroke, and faster time to thrombolysis. Furthermore, each additional prehospital quality measure was associated with a modestly higher odds of a patient with stroke being discharged home, an indirect measure of favorable functional status. Linear association between higher compliance and favorable outcomes combined with relatively low compliance documented for several EMS measures (including prenotification at ≈8% and prehospital stroke screen ≈55%) suggest substantial opportunities to improve EMS documentation, care, and patient outcomes. Further research is needed to validate these relationships and to determine if improved

Table 4. Unadjusted and Adjusted Associations Between the Summary EMS Quality Score (Range, 0–5), Time to Imaging, Time to Treatment, and Patient Outcomes

Logistic regression models*	Positive/total population	Unadjusted odds ratio for each additional quality score point	*P* value	Adjusted odds ratio for each additional quality score point	*P* value
Door-to-CT ≤25 min	3214/5707 EMS-transported strokes	2.4 (2.2 to 2.6)	<0.001	1.5 (1.4 to 1.7)†	<0.001
Thrombolysis if ischemic stroke	959/4732 patients with ischemic stroke/TIA diagnosis	1.7 (1.5 to 1.8)	<0.001	1.1 (1.0 to 1.2)‡	0.026
EVT if ischemic stroke	295/4732 patients with ischemic stroke/TIA diagnosis	1.8 (1.6 to 2.1)	<0.001	1.3 (1.1 to 1.5)‡	0.003
Door-to-Needle ≤45 Minutes	469/959 patients treated with thrombolysis	1.4 (1.2 to 1.6)	<0.001	1.2 (1.0 to 1.4)‡	0.089
Discharge to home (vs other dispositions)	1979/5707 EMS-transported strokes	1.1 (1.0 to 1.1)	0.053	1.1 (1.0 to 1.2)†	0.002
In-hospital mortality	888/5707 EMS-transported strokes	1.0 (0.9 to 1.1)	0.607	1.0 (0.9 to 1.1)†	0.494
Linear regression models*		Unadjusted change in time to outcome (min) for each additional quality score point		Adjusted change in time to outcome (min) for each additional quality score point	
Door-to-CT time	5707 EMS-transported strokes	−17.8 (−19.2 to −16.5)	<0.001	−7.0 (−8.3 to −5.6)†	<0.001
First medical contact to CT	5707 EMS-transported strokes	−20.9 (−22.3 to −19.5)	<0.001	−9.2 (−10.6 to −7.8)†	<0.001
Door-to-needle time	959 patients treated with thrombolysis	−4.3 (−6.2 to −2.5)	<0.001	−2.3 (−4.2 to −0.3)‡	0.021
First medical contact to needle	959 patients treated with thrombolysis	−7.1 (−9.1 to −5.2)	<0.001	−4.3 (−6.4 to −2.2)‡	<0.001

CT indicates computed tomography; EMS, emergency medical services; EVT, endovascular therapy; NIHSS, National Institutes of Health Stroke Scale; and tPA, tissue-type plasminogen activator.

*Models for time to CT included all 5707 EMS-transported stroke cases. Models for tPA and EVT include 4732 ischemic stroke cases. Models for needle time included 959 patients treated with thrombolysis. All models account for clustering by unique agency-hospital pairs.

†Adjusted for age, sex, race, EMS stroke recognition, stroke type, NIHSS, and time from symptom onset.

‡Adjusted for age, sex, race, EMS stroke recognition, NIHSS, and time from symptom onset.

quality scores would translate into improved hospital-based care.

Even before such validation is achieved, this score may be useful to prompt audits of the quality of data uploaded to statewide EMSIS databases. If low rates of documentation of one or more quality measures cluster within a particular EMS agency or EMR software vendor, as we have previously documented,[27] investigation into the documentation practices or software bridges between EMS electronic records and the state EMSIS database may reveal readily correctable data mapping errors. Identification and correction of issues with stroke quality measures may also improve the quality of state-level EMS data relevant to other time-sensitive emergencies such as ST-segment–elevation myocardial infarction or trauma.

This analysis is subject to several important limitations. First, since participating registry hospitals are mostly certified primary or comprehensive stroke centers in larger population centers, application of these findings to small hospitals or rural settings is uncertain. Second, EMS quality metric compliance in the analysis was dependent on both accurate documentation of the care delivered by EMS and on successful transmission of said documentation into the state EMS database (MI-EMSIS). Documentation of EMS care in MI-EMSIS is known to be inconsistent,[22] and the null value for the quality metrics used in this analysis does not and cannot distinguish between failure to comply with the metric and failure to document compliance; thus, it is possible that EMS performance in the field differs meaningfully from that recorded in the MI-EMSIS dataset, as is demonstrated by the wide disparity between EMS and stroke registry–documented prenotification. Third, it is important to recognize that many patients transported by EMS with neurological symptoms ultimately prove to have nonstroke diagnoses. False positive stroke activations for patients with seizure, complex migraine, or other nonstroke disease processes may have unintended negative consequences by diverting resources away from other critical patients; however, this analysis does not address this population. Finally, this observational analysis remains subject to the risk of residual confounding and cannot establish causal relationships between EMS performance and favorable outcomes. It remains to be seen if modification of EMS performance will result in corresponding improvements in hospital-based care and patient outcomes. Interventional studies are needed to study these phenomena.

Compliance with recommended prehospital stroke care is associated with shorter time to stroke diagnostic evaluation and treatment as well as superior patient outcomes. If validated in other settings, a simple summary prehospital quality score for stroke may be useful to identify data integrity issues or target quality improvement interventions.

ARTICLE INFORMATION

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Disclosures

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Supplemental Material

Tables S1–S3
Figures S1–S2

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