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ORIGINAL RESEARCH

Disparities in Emergency Medical Services Time Intervals for Patients with Suspected Acute Coronary Syndrome: Findings from the North Carolina Prehospital Medical Information System

Eric R. Cui, BS; Antonio R. Fernandez, PhD; Jessica K. Zegre-Hemsey, PhD; Joseph M. Grover, MD; Gilson Honvoh, MSPH; Jane H. Brice, MD, MPH; Joseph S. Rossi, MD; Mehul D. Patel, PhD

BACKGROUND: Timely emergency medical services (EMS) response, management, and transport of patients with suspected acute coronary syndrome (ACS) significantly reduce delays to emergency treatment and improve outcomes. We evaluated EMS response, scene, and transport times and adherence to proposed time benchmarks for patients with suspected ACS in North Carolina from 2011 to 2017.

METHODS AND RESULTS: We conducted a population-based, retrospective study with the North Carolina Prehospital Medical Information System, a statewide electronic database of all EMS patient care reports. We analyzed 2011 to 2017 data on patient demographics, incident characteristics, EMS care, and county population density for EMS-suspected patients with ACS, defined as a complaint of chest pain or suspected cardiac event and documentation of myocardial ischemia on prehospital ECG or prehospital activation of the cardiac care team. Descriptive statistics for each EMS time interval were computed. Multivariable logistic regression was used to quantify relationships between meeting response and scene time benchmarks (11 and 15 minutes, respectively) and prespecified covariates. Among 4667 patients meeting eligibility criteria, median response time (8 minutes) was shorter than median scene (16 minutes) and transport (17 minutes) time. While scene times were comparable by population density, patients in rural (versus urban) counties experienced longer response and transport times. Overall, 62% of EMS encounters met the 11-minute response time benchmark and 49% met the 15-minute scene time benchmark. In adjusted regression analyses, EMS encounters of older and female patients and obtaining a 12-lead ECG and venous access were independently associated with lower adherence to the scene time benchmark.

CONCLUSIONS: Our statewide study identified urban–rural differences in response and transport times for suspected ACS as well as patient demographic and EMS care characteristics related to lower adherence to scene time benchmark. Strategies to reduce EMS scene times among patients with ACS need to be developed and evaluated.

Key Words: acute coronary syndrome ■ disparities ■ emergency medical services ■ prehospital delay

Reperfusion therapy with primary percutaneous coronary intervention (PCI) in patients with acute ST-segment–elevation myocardial infarction (STEMI) substantially reduces myocardial injury and improves clinical outcomes.[1] Prolonged time to PCI is associated with poorer outcomes, which has been observed in increments of 10-minute delays.[2–5] Therefore, the overall goal in the early management of patients with STEMI is to provide reperfusion therapy as quickly as possible and minimize total ischemic

Correspondence to: Mehul D. Patel, PhD, Department of Emergency Medicine, 170 Manning Dr, CB# 7594, Chapel Hill, NC 27599-7594.
E-mail: mehul_patel@med.unc.edu

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CLINICAL PERSPECTIVE

What Is New?

- In statewide emergency medical services data on patients with suspected acute coronary syndrome, median emergency medical services response, scene, and transport times were 10, 16, and 17 minutes, respectively.
- Our study found emergency medical services was less likely to respond within the 11-minute benchmark in rural/frontier counties compared with urban counties.
- Older and female patients experienced longer scene times than counterparts. The performance of on-scene venous access procedures was also associated with prolonged scene time.

What Are the Clinical Implications?

- Our study found meaningful differences in emergency medical services time intervals for patients with suspected ACS among patient factors, prehospital care, and population density.
- Interventions to improve the efficiency of on-scene management of patients with suspected ACS have the potential to reduce total ischemic time and improve clinical outcomes.

Nonstandard Abbreviations and Acronyms

NEMSIS National EMS Information System

time.[6] While trends in improved STEMI outcomes have been observed with greater use of PCI, a substantial proportion of patients do not receive reperfusion therapy in a timely manner.[7,8] Current guidelines from the American College of Cardiology Foundation and the American Heart Association recommend a system goal of 90 minutes or less from first medical contact to primary PCI for patients with STEMI.[9] While door-to-balloon times have significantly declined in recent years, concurrent improvements in short-term mortality have not been observed, suggesting the need for additional efforts such as reducing delays before hospital arrival.[3,10]

Emergency medical services (EMS) are integral to the early management of patients with acute coronary syndrome (ACS), including STEMI and non–ST-segment–elevation myocardial infarction. Since EMS is often the first medical contact for these patients, American College of Cardiology Foundation and the American Heart Association guidelines recommend that EMS providers perform 12-lead ECGs for patients with suspected ACS in the field, screen for STEMI criteria at the scene, and directly transport patients to a PCI-capable hospital when possible within recommended time intervals.[11] This regionalized system of prehospital triage and acute care has been shown to reduce delays to PCI and improve patient outcomes.[12–15] EMS management of patients with suspected STEMI is an important component of prehospital time and represents an opportunity to minimize system delays and total ischemic time.[16–18] EMS times are important process measures for optimizing systems of STEMI care.[19] Within a single urban EMS system, Studnek et al. found the likelihood of reperfusion within 90 minutes was greatest for EMS response time limited to 11 minutes and scene time limited to 15 minutes.[20] Overall, there is currently little evidence on the appropriate prehospital time goals for EMS response and management of patients with suspected ACS.

Although there is increasing focus on minimizing prehospital delays to reduce total ischemic time in patients with ACS, there is limited evidence on targeted strategies to improve EMS times for these patients. With a statewide analysis of EMS patient care reports, our study evaluated EMS response, scene, and transport times and adherence to proposed time benchmarks (ie, 11-minute response time and 15-minute scene time) for patients with suspected ACS in North Carolina (NC) from 2011 to 2017. Furthermore, we estimated associations between meeting response and scene time benchmarks and patient, incident, and county characteristics to identify potentially modifiable factors that can be intervened upon to expedite EMS care of patients with ACS.

METHODS

The data that support the findings of this study were obtained from the NC Office of EMS in compliance with requirements for data release and use assuring patient confidentiality and other required healthcare provider protections. Requests to access these data may be sent to the NC Office of EMS (https://info.ncdhhs.gov/dhsr/EMS/ems.htm#contact).

Study Design

We conducted a retrospective analysis of the 2011–2017 NC Prehospital Medical Information System, a statewide electronic database of EMS patient care reports that is used to evaluate and improve EMS performance. Since 2003, all 100 NC county-based EMS systems have been required to collect and submit data into this centralized data system.[21] For the years included, Prehospital Medical Information System collected data using the National EMS

Information System (NEMSIS) Version 2 standard. Data dictionaries and other technical resources are available online at: https://nemsis.org/technical-resources/version-2/version-2-dataset-dictionaries/. Briefly, NEMSIS data include standardized elements describing the EMS encounter including patient demographics, incident times, on-scene assessment and interventions, and incident disposition and transport destination. The study was reviewed in accordance with federal regulations governing human subjects research and approved by the University of North Carolina at Chapel Hill Institutional Review Board. The requirement to obtain informed consent from participants was waived.

Study Population

Our study analyzed EMS care reports for patients with suspected ACS in NC between 2011 and 2017. We defined "suspected ACS" based on criteria used for NC's EMS performance benchmarking and improvement of acute cardiac care. We initially identified patients age 35 years or older with a 9-1-1 call activation requiring an EMS ground response, and who were treated and transported by EMS. Air ambulance responses and interfacility transfers were not included. Next, patients with a suspected cardiac-related complaint were selected by an EMS provider's impression of chest pain or cardiac rhythm disturbance, use of a suspected cardiac patient care protocol, or a 12-lead ECG performed. Among these patients, suspected ACS was identified by prehospital ECG findings of anterior, inferior, or lateral ischemia or prehospital activation of a STEMI center. Since the NEMSIS Version 2 data standard does not include specific ECG markers, such as the ST segment, we were not able to classify patients with suspected ACS as STEMI, non–ST-segment–elevation myocardial infarction, or other ischemia according to the prehospital ECG. Patients who experienced cardiac arrest were excluded because of EMS usual practice of cardiopulmonary resuscitation at the scene rather than prompt transport. Furthermore, EMS encounters with missing or implausible (<1 minute or >24 hours) times were also excluded.

Outcomes

The primary outcomes were EMS time intervals (in minutes) defined as: 9-1-1 call to EMS arrival on scene (response time), EMS arrival on scene to time EMS left scene (scene time), and time left scene to arrival at final destination (transport time). We assessed adherence to response and scene time benchmarks proposed by Studnek et al.[20] with standard EMS time reporting[22] (≤11:59 minutes and ≤15:59 minutes, respectively). Adherence was not computed for transport time because of lack of a recommended benchmark. A transport time benchmark is not appropriate because these times are highly dependent on the distance between incident and destination, which is beyond the control of EMS.

Covariates

We analyzed patient demographics (age, sex, race, and ethnicity), incident characteristics (day of week, and time of day), EMS response (lights and sirens to and from scene, and provider primary and secondary impression). Measures of cardiac care provided by EMS were defined by the documented use of patient care protocols, procedures, and medications. Specifically, relevant data fields were queried for the documentation of Chest Pain/Suspected Cardiac Event protocol, venous access procedure, 12-lead ECG performed, initial ECG finding of ischemia, STEMI center activation, and administration of aspirin, nitroglycerin, morphine, fentanyl, or intravenous fluids (normal saline or lactated Ringer's). If these values were not documented, measures were defined as not provided by EMS. EMS county-based systems were characterized by organization status (volunteer, nonvolunteer, mixed) and by the NEMSIS population density classification (urban, suburban, rural, and frontier).

Statistical Analysis

We generated descriptive statistics for covariates. Frequency counts and percentages were calculated for categorical variables. Frequencies of EMS care related to acute cardiac events were compared by EMS system urbanicity (ie, urban, suburban, and rural/frontier). Medians and interquartile ranges and 90th percentiles were computed for response, scene, and transport time intervals for the overall study population and by urbanicity. We also provide 90th percentiles as useful EMS performance metrics since they represent most patients.[23] Adherence to response and scene time benchmarks is reported as proportions.

Multivariable logistic regression was used to estimate odds ratios (ORs) and 95% CIs between covariate and time benchmark adherence (response and scene). Covariates considered a priori to be potential predictors for time benchmark adherence were included in the models. Covariates that occurred after response time (provider impression, procedures) and therefore were not precursors were not included in the response time model. To minimize the influence of small cells, some covariates (eg, response mode to scene, provider primary impression) were collapsed into fewer categories. A secondary analysis of scene time benchmark adherence was conducted using STEMI center activation as a proxy for patients meeting EMS STEMI criteria. The scene time model was run with product terms between STEMI center activation and each covariate separately, and likelihood ratio tests were conducted to compute *P* values for interactions. Models stratified by STEMI center activation computed ORs and 95% CIs for the secondary analysis. Statistical analyses were performed in SAS 9.4 (SAS, Cary, NC). Given that the study objectives were descriptive and exploratory in nature, we did not perform null hypothesis significance testing with *P* values of ORs and rather focused on the magnitude of relationships quantified with regression models.

RESULTS

The initial query of the 2011 to 2017 Prehospital Medical Information System data set identified 8416 EMS encounters that met criteria for a cardiac-related complaint (Figure 1). The final sample

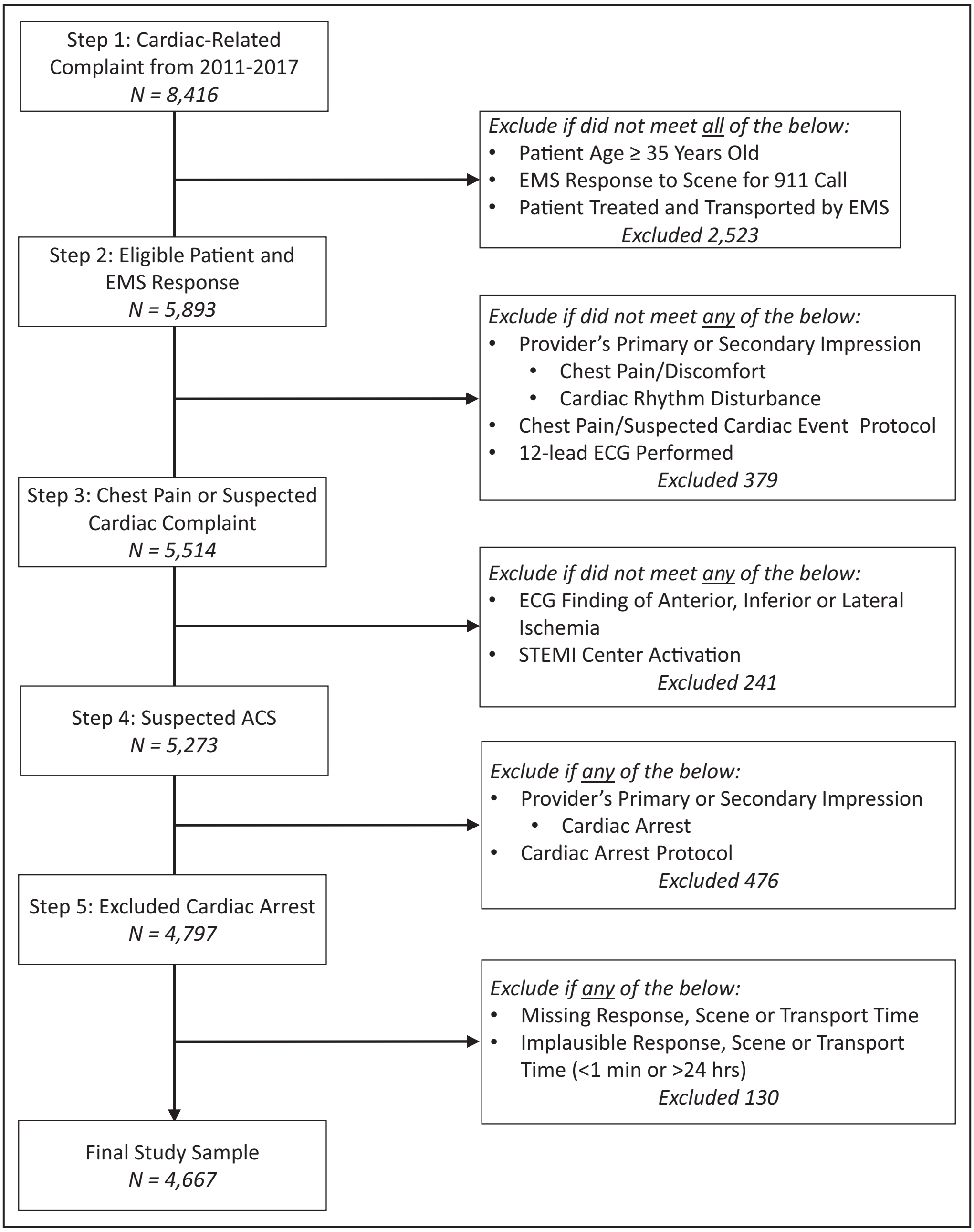

Figure 1. Selection of eligible patients with suspected ACS from the North Carolina prehospital medical information system, 2011 to 2017.
ACS indicates acute coronary syndrome; EMS, emergency medical services; and STEMI, ST-segment–elevation myocardial infarction.

Table 1. Descriptive Statistics of Patient With Suspected ACS and EMS System Characteristics, 2011 to 2017 (N=4667)

Characteristic	No.	%
Age, y		
35–44	345	7
45–54	906	19
55–64	1221	26
65–74	1061	23
75–84	761	16
85+	353	8
Missing	20	0
Sex		
Female	1710	37
Male	2941	63
Missing	16	0
Race		
Black or African American	1122	24
White	3174	68
Other*	161	4
Missing	210	5
Ethnicity		
Hispanic or Latino	108	2
Not Hispanic or Latino	4310	92
Missing	249	5
Incident day of wk		
Weekday	3391	73
Weekend	1276	27
Incident time of day		
11 PM–6:59 AM	915	20
3 PM–10:59 PM	1696	36
7 AM–3 PM	2056	44
Response mode to scene		
Initial lights and sirens, downgraded	14	0
Initial no lights and sirens, upgraded	16	0
Lights and sirens	4270	92
No lights or sirens	367	8
Transport mode from scene		
Initial light and sirens, downgraded	9	0
Initial no lights and sirens, upgraded	185	4
Lights and sirens	3114	67
No lights or sirens	1347	29
Missing	12	0
Provider primary impression		
Cardiac rhythm disturbance	762	16
Altered level of consciousness	96	2
Syncope/fainting	82	2
Respiratory distress	198	4
Chest pain/discomfort	2632	56
Abdominal pain/problems	77	2
Other	105	2
Missing	715	15
Provider secondary impression		
Cardiac rhythm disturbance	365	8
Respiratory distress	123	3
Chest pain/discomfort	275	6
Other	153	3
Missing	3751	80
EMS system urbanicity		
Urban	2993	64
Suburban	1074	23
Rural/frontier	353	8
Missing	247	5

ACS indicates acute coronary syndrome; and EMS, emergency medical services.

*"Other" race includes American Indian or Alaska Native, Asian, Hispanic or Latino ethnicity, Native Hawaiian or Other Pacific Islander, or another race that is not any of the above.

included 4667 patients with suspected ACS who met eligibility criteria for this study. Table 1 describes the general characteristics of our study population. Mean age was 63.9 years (SD, 13.7 years). The study population was predominantly male (63%), White (68%), and not Hispanic or Latino (92%). EMS often responded with lights and sirens (92%) but less often left the scene with lights and sirens (67%). The majority of EMS systems were staffed with non-volunteer providers (93%) and served urban areas (64%).

The most common EMS provider primary impressions in our study population were chest pain (56%) and cardiac rhythm disturbance (16%). Most incidents documented use of a chest pain or suspected cardiac event protocol (78%), and nearly all performed a 12-lead ECG (89%), which were comparable across urban, suburban, and rural/frontier systems (Table 2). Half (50%) of patients had ECG findings of anterior, inferior, or lateral ischemia. A STEMI center was activated by EMS in 61% of incidents. ECG findings of ischemia were more frequent in rural (77%) compared with urban (41%) systems, whereas STEMI activations were more frequent in urban (71%) compared with rural (30%) systems. Almost all patients (94%) had a venous access procedure. Aspirin and nitroglycerin were the most frequently administered medications (62% and 57%, respectively), whereas morphine, commonly administered intravenously, was provided much less frequently (13%). Still, morphine use occurred twice as often in rural/frontier (19%) and suburban (20%) compared with urban (9%) systems. Intravenous fluids were administered to 39% of patients and similarly across systems.

Table 2. Frequency of EMS Cardiac Care for Patients With Suspected ACS, Overall and by Urbanicity

EMS cardiac care measures	Overall (N=4667)	EMS system urbanicity		
		Urban (N=2993)	Suburban (N=1074)	Rural/Frontier (N=353)
Chest pain/suspected cardiac event protocol used	78%	78%	77%	80%
12-Lead ECG performed	89%	90%	89%	83%
ECG finding of ischemia	50%	41%	62%	77%
STEMI center activation	61%	71%	49%	30%
Venous access procedure	94%	94%	95%	90%
Medications administered				
Aspirin	62%	61%	67%	59%
Nitroglycerin	57%	56%	61%	55%
Morphine	13%	9%	20%	19%
Fentanyl	4%	4%	3%	6%
Fluids (normal saline or lactated Ringer's)	39%	41%	35%	41%

ACS indicates acute coronary syndrome; EMS, emergency medical services; and STEMI, ST-segment–elevation myocardial infarction.

Median EMS response time was 10 minutes (interquartile range, 7–14). Median scene and transport time were substantially longer (16 minutes [interquartile range, 12–20] and 17 minutes [interquartile range, 10–28], respectively). Median scene and response times were comparable by urbanicity, whereas median transport times were substantially longer in suburban and rural/frontier systems (additional 10 and 11 minutes, respectively) compared with urban systems (Figure 2).

Overall, 62% of EMS encounters met the 11-minute response time benchmark and 49% of EMS encounters met the 15-minute scene time benchmark. Multivariable logistic regression quantified relationships between covariates and meeting response and scene time benchmarks (Table 3). Encounters that took place later in the day (3 PM–10:59 PM, OR, 0.74, 95% CI, 0.64–0.86; 11 PM–6:59 AM, OR, 0.53, 95% CI, 0.45–0.63) were less likely to meet response time benchmarks

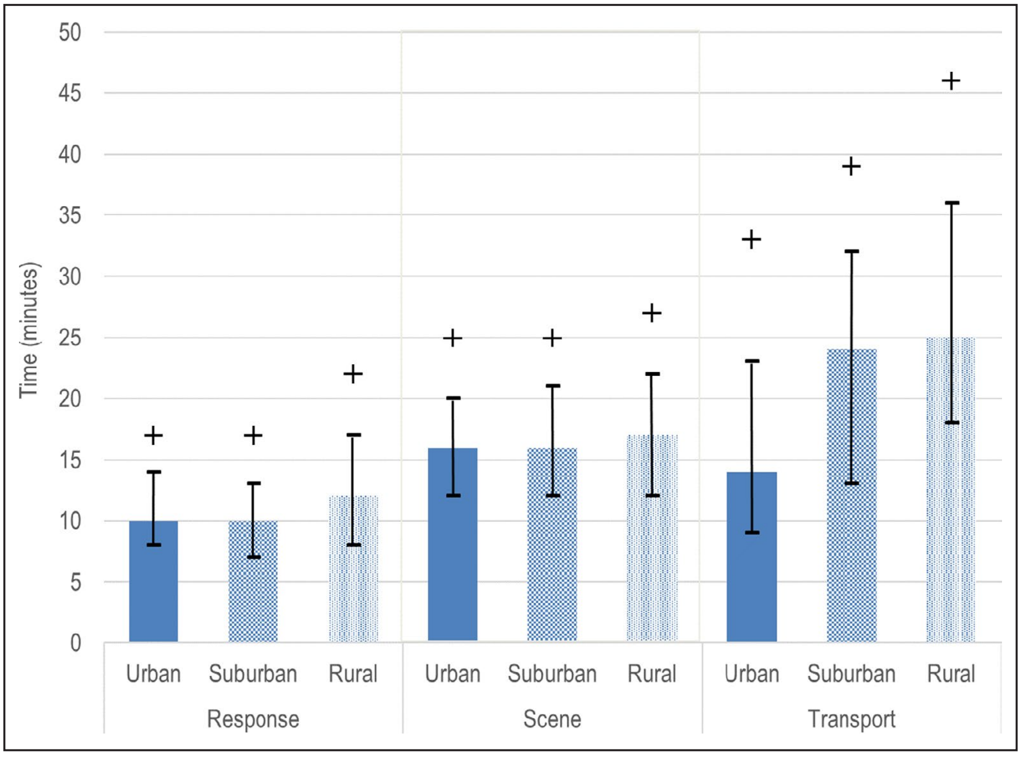

Figure 2. Median (bar), interquartile range (error bar), and 90th percentile (plus) EMS times for suspected ACS by EMS system urbanicity.
ACS indicates acute coronary syndrome; and EMS, emergency medical services.

Table 3. Associations Among Demographic, Clinical, Response, and Geographic Characteristics and Adherence to Response and Scene Time Benchmarks

Covariates	Response time ≤11:59 min (N=4196)			Scene time ≤15:59 min (N=3565)		
	Freq. (%)	OR	95% CI	Freq. (%)	OR	95% CI
Age group						
35–44, y	67.0	1.26	0.96–1.66	60.6	1.40	1.05–1.87
45–54, y	60.7	0.98	0.81–1.18	58.6	1.37	1.12–1.68
55–64, y (ref)	61.3	1	…	51.0	1	…
65–74, y	61.6	0.99	0.83–1.19	48.6	0.97	0.80–1.17
75–85, y	63.1	1.10	0.90–1.35	40.4	0.74	0.60–0.92
>85, y	65.3	1.13	0.86–1.47	35.6	0.63	0.47–0.85
Sex						
Female	62.3	1.00	0.87–1.14	41.2	0.63	0.55–0.73
Male (ref)	62.3	1	…	54.7	1	…
Race						
Black or African American	62.2	0.99	0.85–1.15	51.0	0.97	0.83–1.14
White (ref)	62.9	1	…	48.7	1	…
Other*	50.0	0.57	0.41–0.80	60.9	1.65	1.13–2.39
Incident d of wk						
Weekday (Mon–Fri) (ref)	61.0	1	…	49.7	1	…
Weekend (Sat–Sun)	65.7	1.22	1.05–1.41	49.8	0.98	0.84–1.14
Incident time of d						
7 AM–2:59 PM (ref)	67.5	1	…	52.5	1	…
3 PM–10:59 PM	60.9	0.74	0.64–0.86	49.0	0.82	0.70–0.95
11 PM–6:59 AM	53.1	0.53	0.45–0.63	45.2	0.68	0.57–0.82
Response mode to scene						
Lights and siren (entire ride) (ref)	63.4	1	…	50.8	1	…
Other†	49.7	0.54	0.44–0.68	37.6	0.63	0.49–0.82
Urbanicity						
Urban (ref)	62.6	1	…	50.7	1	…
Suburban	66.1	1.24	1.06–1.45	49.3	1.08	0.91–1.29
Rural/Frontier	47.6	0.55	0.44–0.70	43.2	0.81	0.62–1.06
Provider primary impression						
Chest pain	…	…	…	55.0	1.71	1.46–2.01
Other (ref)	…	…	…	39.5	1	…
Chest pain/suspected cardiac event protocol used						
Yes	…	…	…	52.1	1.09	0.90–1.31
No (ref)	…	…	…	40.3	1	…
12-Lead ECG performed						
Yes	…	…	…	49.0	0.77	0.62–0.96
No (ref)	…	…	…	55.6	1	…
Venous access procedure						
Yes	…	…	…	49.3	0.66	0.49–0.89
No (ref)	…	…	…	56.9	1	…
STEMI center activation						
Yes	…	…	…	52.6	1.47	1.25–1.71
No (ref)	…	…	…	44.5	1	…

OR indicates odds ratio; and STEMI, ST-segment–elevation myocardial infarction.

*"Other" race includes American Indian or Alaska Native, Asian, Hispanic or Latino ethnicity, Native Hawaiian or Other Pacific Islander, or another race that is not any of the above.

†"Other" response mode to scene includes no lights and sirens, initial light and sirens and downgraded, and initial no lights and sirens and upgraded.

compared with incidents between 7 AM and 2:59 PM. Encounters that occurred on the weekend were more likely to meet response time benchmarks (OR, 1.22; 95% CI, 1.05–1.41). An EMS response without lights and sirens was associated with a lower likelihood of meeting the response time benchmarks (OR, 0.54; 95% CI, 0.44–0.68). Incidents in rural/frontier regions were less likely to meet response time benchmarks (OR, 0.55; 95% CI, 0.44–0.70), while those in suburban regions were more likely to meet response time benchmarks (OR, 1.24; 95% CI, 1.06–1.45).

Meeting the scene time benchmark was less likely with increasing patient age (Table 3). Females were also less likely to meet the scene time benchmark (OR, 0.63; 95% CI, 0.55–0.73). An EMS response without lights and sirens was associated with a lower likelihood of meeting the scene time benchmarks (OR, 0.63; 95% CI, 0.49–0.82). An EMS provider primary impression of chest pain (OR, 1.71; 95% CI, 1.46–2.01) and a STEMI center activation (OR, 1.47; 95% CI, 1.25–1.71) were more likely to meet the scene time benchmark, whereas performing a 12-lead ECG (OR, 0.77; 95% CI, 0.62–0.96) and venous access procedure (OR, 0.66; 95% CI, 0.49–0.89) at the scene had a lower likelihood of adherence. In a secondary analysis of STEMI center activations, stratified regression estimates for other covariates, including patient age and sex and 12-lead ECG and venous access procedures, were mostly comparable (Table 4). However, when a STEMI center was activated, incidents in rural/frontier regions compared with urban regions were less likely to meet the scene time benchmark (OR, 0.56; 95% CI, 0.35–0.90).

DISCUSSION

In our analysis of NC EMS encounters of patients with suspected ACS, we found that a substantial proportion did not meet proposed response and scene time benchmarks. Specifically, more than one third of EMS encounters did not meet the 11-minute response time benchmark and about half did not meet the 15-minute scene time benchmark. Moreover, the 90th percentiles of response, scene, and transport times suggest some patients are experiencing long and clinically significant delays (eg, up to 25 minutes on scene). Our study demonstrates that EMS time intervals are meaningful contributors to overall prehospital time for patients with suspected ACS. Interventions that improve EMS efficiency and maintain safety for patients and providers may reduce total ischemic time and improve clinical outcomes for time-sensitive patients with ACS.

Scene time represents a potentially modifiable contributor to total EMS time. Our study found that older and female patients experienced longer scene times, even when a STEMI center was activated. Older patients possibly present with more comorbidities requiring longer on-scene evaluation and management. Addressing this age disparity in EMS protocols and continuing education may be warranted. Longer scene times for female patients and evidence that women are treated less urgently for cardiac conditions have been noted elsewhere.[24–28] Since many women with ACS present with symptoms other than classic chest pain, EMS providers may not be recognizing these symptoms as quickly or treating with the same urgency as for men. Our analysis adjusted for EMS provider impression of chest pain, yet the sex disparity persisted. Further monitoring of these age and sex differences is needed in addition to future research into addressing these disparities. For example, an audible on-scene timer is a potential equitable solution to improve scene times.[29]

We found that several prehospital cardiac care measures were related to meeting the EMS scene time benchmark. An EMS provider primary impression of chest pain and a STEMI center activation were independently associated with shorter scene times, which were likely because of a heightened sense of urgency among the EMS personnel. Prehospital activation of the cardiac catheterization laboratory is known to expedite care once the patient arrives at the hospital.[30,31] A recent statewide survey found that only 61% of NC EMS systems had a written policy to activate the cardiac catheterization laboratory from the field.[32] We were, however, not able to evaluate this system-level variation in our analysis of 2011 to 2017 data. Although we adjusted for urbanicity to account for urban–rural differences in STEMI activations by EMS, the relationship with reduced scene time may be driven by a system-level effect rather than the practice itself. In the stratified secondary analysis, we found that rural EMS was least likely to meet the scene time benchmark when a STEMI center was activated, which will be important to better understand in future studies. We found that performing a 12-lead ECG was associated with longer scene time, with STEMI center activation or not. However, prehospital 12-lead ECG is essential to early STEMI identification,[11,33] and its benefits are likely outweighed by the cost of additional time spent at the scene. Overall, NC has high prehospital ECG utilization. In our data, almost 90% of patients had an ECG obtained in the field. Bush et al. observed that 65% of patients with chest pain in NC in 2010 received a prehospital ECG, and since then, the state has used grant funding to purchase and place ECG equipment in ambulances across NC.[34] In a region such as NC where prehospital ECG is widely utilized, interventions to expedite ECG acquisition and interpretation could be investigated, such

Table 4. Associations Among Demographic, Clinical, Response, and Geographic Characteristics and Adherence to Scene Time Benchmark Stratified by STEMI Center Activation

Covariates	STEMI center activation (N=2322)			No STEMI center activation (N=1243)			Interaction *P* Value*
	Freq. (%)	OR	95% CI	Freq. (%)	OR	95% CI	
Age group, y							
35–44	64.3	1.42	0.98–2.04	53.4	1.41	0.87–2.28	0.31
45–54	62.8	1.43	1.10–1.85	51.2	1.32	0.95–1.84	
55–64 (ref)	55.1	1	…	44.0	1	…	
65–74	52.2	0.95	0.75–1.22	41.8	0.99	0.72–1.36	
75–85	40.4	0.66	0.50–0.86	40.4	0.98	0.67–1.43	
>85	36.1	0.58	0.40–0.83	34.5	0.75	0.45–1.25	
Sex							
Female	43.5	0.63	0.53–0.76	36.8	0.64	0.50–0.82	0.62
Male (ref)	57.9	1	…	48.9	1	…	
Race							
Black or African American	53.0	0.96	0.79–1.17	45.3	0.93	0.70–1.25	0.93
White (ref)	51.7	1	…	43.7	1	…	
Other†	64.6	1.79	1.10–2.90	54.9	1.36	0.75–2.46	
Incident d of wk							
Weekday (Mon-Fri) (ref)	52.6	1	…	44.7	1	…	0.78
Weekend (Sat–Sun)	52.7	0.99	0.82–1.20	43.9	0.94	0.72–1.22	
Incident time of day							
7 AM–2:59 PM (ref)	56.1	1	…	46.0	1	…	0.30
3 PM–10:59 PM	52.4	0.82	0.67–0.99	42.9	0.82	0.63–1.05	
11 PM–6:59 AM	45.7	0.61	0.49–0.77	44.1	0.84	0.61–1.17	
Response mode to scene							
Lights and siren (entire ride) (ref)	54.1	1	…	44.5	1	…	<0.01
Other‡	32.9	0.48	0.34–0.69	44.4	0.95	0.64–1.42	
Urbanicity							
Urban (ref)	53.8	1	…	40.8	1	…	0.02
Suburban	49.4	0.95	0.74–1.22	49.2	1.34	1.03–1.74	
Rural/frontier	38.1	0.56	0.35–0.90	45.3	1.09	0.78–1.52	
Provider primary impression							
Chest pain	58.8	1.91	1.57–2.34	47.7	1.31	0.99–1.73	<0.01
Other (ref)	40.1	1	…	38.4	1	…	
Chest pain/suspected cardiac event protocol used							
Yes	55.1	1.15	0.89–1.47	46.1	1.06	0.78–1.44	0.09
No (ref)	40.7	1	…	39.6	1	…	
12-lead ECG performed							
Yes	52.1	0.82	0.61–1.11	43.0	0.77	0.56–1.07	0.70
No (ref)	58.0	1	…	52.9	1	…	
Venous access procedure							
Yes	52.3	0.72	0.48–1.08	43.6	0.66	0.43–1.01	0.63
No (ref)	59.1	1	…	54.5	1	…	

OR indicates odds ratio; and STEMI, ST-segment–elevation myocardial infarction.
*Interaction *P* values were computed using likelihood ratio tests comparing models with and without product terms.
†"Other" race includes American Indian or Alaska Native, Asian, Hispanic or Latino ethnicity, Native Hawaiian or Other Pacific Islander, or another race that is not any of the above.
‡"Other" response mode to scene includes no lights and sirens, initial light and sirens and downgraded, and initial no lights and sirens and upgraded.

as simulation training for EMS providers or expanding technical capabilities for electronically transmitting ECGs for physician interpretation.

We also found that performing a venous access procedure was associated with longer scene time, regardless of STEMI center activation. Compared with prehospital ECG, less evidence is available about the benefits of prehospital venous access for patients with ACS.[35] Relative to the proportion of patients with venous access in our study, the use of morphine and fentanyl, which can be administered intravenously or intramuscularly, was very infrequent, and <40% of patients received intravenous fluids, suggesting that venous access may not be useful for most patients with ACS. To minimize time spent on scene, EMS providers could attempt venous access only when clinically needed, such as for the administration of intravenous fluids or medications, or during transport to the hospital. Compared with venous access procedures, we found relatively low administration of aspirin, which is consistent with prior research[36] and suggests that although patients may be self-administering aspirin before EMS arrival, there is a need to evaluate and improve protocol adherence. Overall, our study highlights the need for more efficiency in the on-scene management of patients with suspected ACS through streamlined patient care protocols, provider simulation training, or other process improvement methods.

While we reported the frequency of prehospital cardiac care measures, EMS provider impression, patient care protocols, and on-scene procedures were used as inclusion criteria, so these frequencies were influenced by selection into the study population. Notably, we observed that patients with suspected ACS in rural EMS systems were more likely to have documented ischemia than urban systems, whereas urban systems were much more likely to have a documented STEMI center activation. We posit that rural EMS providers activate STEMI centers from the field less often if at all because they are less likely to transport to PCI-capable hospitals, which are concentrated in urban areas. Therefore, we believe the greater documented ischemia in rural patients is an artifact of the patient selection process rather than differences in case mix between rural and urban EMS systems. These issues are inherent to prehospital research using electronic health records. With a focus on EMS care, we defined eligible encounters using information available to EMS in the field as would be done in prospective prehospital research rather than using a definitive clinical diagnosis.[37]

Although the clinical benefit of reducing EMS response times is not established, response time remains a common and important metric for EMS system performance. Our study found slower responses to patients with suspected ACS during off-peak hours and on weekdays, which are likely because of fewer units in service during off-peak hours and greater 9-1-1 call volume and traffic on weekdays. Associations of EMS response times with time of day and day of week in other patient populations have been reported.[38] As observed in our prior national study of EMS times for patients experiencing chest pain,[39] EMS units responding with lights and sirens had substantially faster response times. Further investigation into 9-1-1 calls for patients with suspected ACS could reveal opportunities for emergency medical dispatch to elevate the priority of these complaints. Also consistent with our prior study,[39] EMS responses took longer in rural areas, which is likely because of longer travel distances. While a standard 8-minute benchmark for all EMS responses is commonly used, recent evidence supports an 11-minute benchmark for complaints with suspicion of STEMI.[20] Our results suggest neither goal is feasible for rural EMS systems under the current level of resources. Rural EMS systems may be able to achieve recommended response times by optimizing the placement of ambulance units or increasing the number of them in service.

Although there is no recommended or proposed time benchmark for EMS transports of patients with suspected ACS, our results show that transport time constitutes a significant portion of EMS time for these patients. The Reperfusion of Acute Myocardial Infarction in North Carolina Emergency Department program began in 2006 and with the NC Office of EMS in 2008 implemented a STEMI triage and destination plan for EMS to bypass non-PCI hospitals.[14] Fosbol et al. reported that the majority of patients with STEMI in NC from 2008 to 2010 were transported to a PCI-capable center and had significantly shorter times to reperfusion.[14] This regionalized system of care may partially account for the substantially longer transport times in rural areas observed in our study. In our study, longer transport times in rural areas may also be explained by greater distances to the closest hospital. Primary transport with helicopter EMS has the potential to reduce overall system delays in rural settings compared with those in urban settings.[40] Still, rather than benchmarking EMS transport times for patients with ACS, overall system time to appropriate hospital care (eg, time to a PCI-capable center for patients with suspected STEMI) should be monitored and evaluated.

There are important limitations of our study that need to be considered. First, we conducted a retrospective analysis of a statewide electronic database. As noted, prehospital ECG abnormalities were not captured in this data source and did not allow us to restrict analyses to patients meeting STEMI criteria according to EMS. However, our secondary analysis among STEMI center activations provides insight into prehospital care of urgent, time-sensitive patients. Although our identification of eligible patients purposefully used only information available to EMS, information on final diagnosis was not available, and we were not able to differentiate between STEMI, non–ST-segment–elevation myocardial infarction, and other clinical conditions in our data. Still, our analysis of EMS patients with suspected ACS is informative for evaluating EMS system performance because it reflects actual practice in the field where final diagnoses are not determined or known. Second, the EMS time benchmarks evaluated in our study are based on evidence from a single study of patients with STEMI[20] and have not been established in evidence-based clinical guidelines for all patients with ACS. These benchmarks need to be revisited, particularly with respect to urban–rural differences, in future research. Third, we found the geographic distribution of our study population was not representative of NC, and some populous counties were underrepresented in our study. This under-ascertainment is likely because of how data from individual EMS agencies were collected and mapped to the NC Prehospital Medical Information System database, which at the time was using NEMSIS Version 2, whereas some EMS agencies were collecting data in Version 3, and missing data because of software version are agency-specific and unlikely to bias the results of this study. While the study data may not be representative of NC, >4000 EMS encounters were included across a large region with a diverse population and representation from urban, suburban, and rural areas, which allowed for valid urban–rural comparisons. Lastly, our data only covered care received in the prehospital setting, so we could not evaluate transports or transfers to PCI-capable centers, in-hospital care, and patient outcomes. Future research should investigate the contribution of EMS care practices in reducing total ischemic time. For example, while performing and interpreting ECGs may prolong scene times, there could be significant downstream advantages to reducing time to emergency treatment. In addition, rural EMS providers may be underutilizing activating the STEMI center when it can be more beneficial to their patients who tend to experience longer transport times.

In conclusion, our statewide study revealed room for improvement in EMS adherence to response and scene time benchmarks for patients with suspected ACS. In addition, we found patient age and sex, EMS on-scene care measures, and population density were related to significant differences in EMS time intervals. These findings will inform future research into EMS system-level interventions and strategies to improve the efficiency of prehospital care and minimize total ischemic time for patients with ACS.

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Affiliations

Department of Emergency Medicine, School of Medicine (E.R.C., A.R.F., J.M.G., J.H.B., M.D.P.); School of Information and Library Science (E.R.C.); and School of Nursing (J.K.Z.), University of North Carolina at Chapel Hill, Chapel Hill, NC; ESO, Austin, TX (A.R.F.); Department of Biostatistics, Gillings School of Global Public Health (G.H.); and Division of Cardiology, Department of Medicine (J.S.R.), University of North Carolina at Chapel Hill, Chapel Hill, NC; and Orange County Emergency Services, Hillsborough, NC (J.M.G.).

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REFERENCES

1. Huynh T, Perron S, O'Loughlin J, Joseph L, Labrecque M, Tu JV, Théroux P. Comparison of primary percutaneous coronary intervention and fibrinolytic therapy in ST-segment–elevation myocardial infarction: bayesian hierarchical meta-analyses of randomized controlled trials and observational studies. *Circulation*. 2009;119:3101–3109. DOI: 10.1161/CIRCULATIONAHA.108.793745.
2. Lambert L, Brown K, Segal E, Brophy J, Rodes-Cabau J, Bogaty P. Association between timeliness of reperfusion therapy and clinical outcomes in ST-elevation myocardial infarction. *JAMA*. 2010;303:2148–2155. DOI: 10.1001/jama.2010.712.
3. Nallamothu BK, Normand SL, Wang Y, Hofer TP, Brush JE Jr, Messenger JC, Bradley EH, Rumsfeld JS, Krumholz HM. Relation between door-to-balloon times and mortality after primary percutaneous coronary intervention over time: a retrospective study. *Lancet*. 2015;385:1114–1122. DOI: 10.1016/S0140-6736(14)61932-2.
4. Scholz KH, Maier SKG, Maier LS, Lengenfelder B, Jacobshagen C, Jung J, Fleischmann C, Werner GS, Olbrich HG, Ott R, et al. Impact of treatment delay on mortality in ST-segment elevation myocardial infarction (STEMI) patients presenting with and without haemodynamic instability: results from the German prospective, multicentre FITT-STEMI trial. *Eur Heart J*. 2018;39:1065–1074. DOI: 10.1093/eurheartj/ehy004.
5. Nepper-Christensen L, Lønborg J, Høfsten DE, Ahtarovski KA, Kyhl K, Göransson C, Køber L, Helqvist S, Pedersen F, Kelbæk H, et al. Impact of diagnostic ECG-to-wire delay in STEMI patients treated with primary PCI: a DANAMI-3 substudy. *EuroIntervention*. 2018;14:700–707. DOI: 10.4244/EIJ-D-17-00857.
6. Antman EM, Hand M, Armstrong PW, Bates ER, Green LA, Halasyamani LK, Hochman JS, Krumholz HM, Lamas GA, Mullany CJ, et al. 2007 focused update of the ACC/AHA 2004 guidelines for the management of patients with ST-elevation myocardial infarction. *Circulation*. 2008;117:296–329. DOI: 10.1161/CIRCULATIONAHA.107.188209.
7. Nallamothu BK, Bates ER, Herrin J, Wang Y, Bradley EH, Krumholz HM, NRMI Investigators. Times to treatment in transfer patients undergoing primary percutaneous coronary intervention in the United States: National Registry of Myocardial Infarction (NRMI)-3/4 analysis. *Circulation*. 2005;111:761–767. DOI: 10.1161/01.CIR.0000155258.44268.F8.
8. Chakrabarti A, Krumholz HM, Wang Y, Rumsfeld JS, Nallamothu BK, National Cardiovascular Data Registry. Time-to-reperfusion in

patients undergoing interhospital transfer for primary percutaneous coronary intervention in the U.S: an analysis of 2005 and 2006 data from the National Cardiovascular Data Registry. *J Am Coll Cardiol*. 2008;51:2442–2443. DOI: 10.1016/j.jacc.2008.02.071.

9. O'Gara PT, Kushner FG, Ascheim DD, Casey DE, Chung MK, de Lemos JA, Ettinger SM, Fang JC, Fesmire FM, Franklin BA, et al. 2013 ACCF/AHA guideline for the management of ST-elevation myocardial infarction: a report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines. *Circulation*. 2013;127:e362–e425. DOI: 10.1161/CIR.0b013e3182742cf6.
10. Menees DS, Peterson ED, Wang Y, Curtis JP, Messenger JC, Rumsfeld JS, Gurm HS. Door-to-balloon time and mortality among patients undergoing primary PCI. *N Engl J Med*. 2013;369:901–909. DOI: 10.1056/NEJMoa1208200.
11. Ting HH, Krumholz HM, Bradley EH, Cone DC, Curtis JP, Drew BJ, Field JM, French WJ, Gibler WB, Goff DC, et al. Implementation and integration of prehospital ECGs into systems of care for acute coronary syndrome: a scientific statement from the American Heart Association Interdisciplinary Council on Quality of Care and Outcomes Research, Emergency Cardiovascular Care Committee, Council on Cardiovascular Nursing, and Council on Clinical Cardiology. *Circulation*. 2008;118:1066–1079. DOI: 10.1161/CIRCULATIONAHA.108.190402.
12. Le May MR, So DY, Dionne R, Glover CA, Froeschl MPV, Wells GA, Davies RF, Sherrard HL, Maloney J, Marquis J-F, et al. A citywide protocol for primary PCI in ST-segment elevation myocardial infarction. *N Engl J Med*. 2008;358:231–240. DOI: 10.1056/NEJMoa073102.
13. Bagai A, Jollis JG, Dauerman HL, Peng SA, Rokos IC, Bates ER, French WJ, Granger CB, Roe MT. Emergency department bypass for ST-segment–elevation myocardial infarction patients identified with a prehospital electrocardiogram: a report from the American Heart Association Mission: lifeline program. *Circulation*. 2013;128:352–359. DOI: 10.1161/CIRCULATIONAHA.113.002339.
14. Fosbol EL, Granger CB, Jollis JG, Monk L, Lin LI, Lytle BL, Xian Y, Garvey JL, Mears G, Corbett CC, et al. The impact of a statewide pre-hospital STEMI strategy to bypass hospitals without percutaneous coronary intervention capability on treatment times. *Circulation*. 2013;127:604–612. DOI: 10.1161/CIRCULATIONAHA.112.118463.
15. Fordyce CB, Henry TD, Granger CB. Implementation of regional ST-segment elevation myocardial infarction systems of care: successes and challenges. *Interv Cardiol Clin*. 2016;5:415–425. DOI: 10.1016/j.iccl.2016.06.001.
16. Terkelsen CJ, Sørensen JT, Maeng M, Jensen LO, Tilsted HH, Trautner S, Vach W, Johnsen SP, Thuesen L, Lassen JF. System delay and mortality among patients with STEMI treated with primary percutaneous coronary intervention. *JAMA*. 2010;304:763–771. DOI: 10.1001/jama.2010.1139.
17. Studnek JR, Infinger A, Wilson H, Niess G, Jackson P, Swanson D. Decreased time from 9-1-1 call to PCI among patients experiencing STEMI results in a decreased one year mortality. *Prehosp Emerg Care*. 2018;22:669–675. DOI: 10.1080/10903127.2018.1447621.
18. Żurowska-Wolak M, Piekos P, Jąkała J, Mikos M. The effects of prehospital system delays on the treatment efficacy of STEMI patients. *Scand J Trauma Resusc Emerg Med*. 2019;27:39. DOI: 10.1186/s13049-019-0616-4.
19. Jollis JG, Al-Khalidi HR, Monk L, Roettig ML, Garvey JL, Aluko AO, Wilson BH, Applegate RJ, Mears G, Corbett CC, et al. Expansion of a regional ST-segment–elevation myocardial infarction system to an entire state. *Circulation*. 2012;126:189–195. DOI: 10.1161/CIRCULATIONAHA.111.068049.
20. Studnek JR, Garvey L, Blackwell T, Vandeventer S, Ward SR. Association between prehospital time intervals and ST-elevation myocardial infarction system performance. *Circulation*. 2010;122:1464–1469. DOI: 10.1161/CIRCULATIONAHA.109.931154.
21. Mears GD, Pratt D, Glickman SW, Brice JH, Glickman LT, Cabañas JG, Cairns CB. The North Carolina EMS data system: a comprehensive integrated emergency medical services quality improvement program. *Prehosp Emerg Care*. 2010;14:85–94. DOI: 10.3109/10903120903349846.
22. Austin PC, Schull MJ. Quantile regression: a statistical tool for out-of-hospital research. *Acad Emerg Med*. 2003;10:789–797. DOI: 10.1197/aemj.10.7.789.
23. Do YK, Foo K, Ng YY, Ong ME. A quantile regression analysis of ambulance response time. *Prehosp Emerg Care*. 2013;17:170–176. DOI: 10.3109/10903127.2012.729127.
24. Lewis JF, Zeger SL, Li X, Mann NC, Newgard CD, Haynes S, Wood SF, Dai M, Simon AE, McCarthy ML. Gender differences in the quality of EMS care nationwide for chest pain and out-of-hospital cardiac arrest. *Womens Health Issues*. 2019;29:116–124. DOI: 10.1016/j.whi.2018.10.007.
25. Aguilar SA, Patel M, Castillo E, Patel E, Fisher R, Ochs G, Pringle J, Ehtisham M, Dunford JV. Gender differences in scene time, transport time, and total scene to hospital arrival time determined by the use of a prehospital electrocardiogram in patients with complaint of chest pain. *J Emerg Med*. 2012;43:291–297. DOI: 10.1016/j.jemermed.2011.06.130.
26. Concannon TW, Griffith JL, Kent DM, Normand SL, Newhouse JP, Atkins J, Beshansky JR, Selker HP. Elapsed time in emergency medical services for patients with cardiac complaints: are some patients at greater risk for delay? *Circ Cardiovasc Qual Outcomes*. 2009;2:9–15. DOI: 10.1161/CIRCOUTCOMES.108.813741.
27. Pezzin LE, Keyl PM, Green GB. Disparities in the emergency department evaluation of chest pain patients. *Acad Emerg Med*. 2007;14:149–156. DOI: 10.1197/j.aem.2006.08.020.
28. Lopez L, Wilper AP, Cervantes MC, Betancourt JR, Green AR. Racial and sex differences in emergency department triage assessment and test ordering for chest pain, 1997–2006. *Acad Emerg Med*. 2010;17:801–808. DOI: 10.1111/j.1553-2712.2010.00823.x.
29. Curtis L, ter Avest E, Griggs J, Wiliams J, Lyon RM. The ticking clock: does actively making an enhanced care team aware of the passage of time improve pre-hospital scene time following traumatic incidents? *Scand J Trauma Resusc Emerg Med*. 2020;28:1–8. DOI: 10.1186/s13049-020-00726-9.
30. Cone DC, Lee CH, Gelder CV. EMS activation of the cardiac catheterization laboratory is associated with process improvements in the care of myocardial infarction patients. *Prehosp Emerg Care*. 2013;17:293–298. DOI: 10.3109/10903127.2013.773112.
31. Kobayashi A, Misumida N, Aoi S, Steinberg E, Kearney K, Fox JT, Kane Y. STEMI notification by EMS predicts shorter door-to-balloon time and smaller infarct size. *Am J Emerg Med*. 2016;34:1610–1613. DOI: 10.1016/j.ajem.2016.06.022.
32. Zègre-Hemsey JK, Patel MD, Fernandez AR, Pelter MM, Brice J, Rosamond W. A statewide assessment of prehospital electrocardiography approaches of acquisition and interpretation for ST-elevation myocardial infarction based on emergency medical services characteristics. *Prehosp Emerg Care*. 2020;24:550–556. DOI: 10.1080/10903127.2019.1677831.
33. Diercks DB, Kontos MC, Chen AY, Pollack CV, Wiviott SD, Rumsfeld JS, Magid DJ, Gibler WB, Cannon CP, Peterson ED, et al. Utilization and impact of pre-hospital electrocardiograms for patients with acute ST-segment elevation myocardial infarction: data from the NCDR (National Cardiovascular Data Registry) ACTION (Acute Coronary Treatment and Intervention Outcomes Network) registry. *J Am Coll Cardiol*. 2009;53:161–166. DOI: 10.1016/j.jacc.2008.09.030.
34. Bush M, Glickman LT, Fernandez AR, Garvey JL, Glickman SW. Variation in the use of 12-lead electrocardiography for patients with chest pain by emergency medical services in North Carolina. *J Am Heart Assoc*. 2013;2:e000289. DOI: 10.1161/JAHA.113.000289.
35. Millin MG, Brooks SC, Travers A, Megargel RE, Colella MR, Rosenbaum RA, Aufderheide TP. Emergency medical services management of ST-elevation myocardial infarction. *Prehosp Emerg Care*. 2008;12:395–403. DOI: 10.1080/10903120802099310.
36. Tataris KL, Mercer MP, Govindarajan P. Prehospital aspirin administration for Acute Coronary Syndrome (ACS) in the USA: an EMS quality assessment using the NEMSIS 2011 database. *Emerg Med J*. 2015;32:876–881. DOI: 10.1136/emermed-2014-204299.
37. Newgard CD, Fu R, Malveau S, Rea T, Griffiths DE, Bulger E, Klotz P, Tirrell A, Zive D. Out-of-hospital research in the era of electronic health records. *Prehosp Emerg Care*. 2018;22:539–550. DOI: 10.1080/10903127.2018.1430875.
38. Nehme Z, Andrew E, Smith K. Factors influencing the timeliness of emergency medical service response to time critical emergencies. *Prehosp Emerg Care*. 2016;20:783–791. DOI: 10.3109/10903127.2016.1164776.
39. Cui ER, Beja-Glasser A, Fernandez AR, Grover JM, Mann NC, Patel MD. Emergency medical services time intervals for acute chest pain in the United States, 2015–2016. *Prehosp Emerg Care*. 2020;24:557–565. DOI: 10.1080/10903127.2019.1676346.
40. Moens D, Stipulante S, Donneau A, Hartstein G, Pirotte O, D'orio V, Ghuysen A. Air versus ground transport of patients with acute myocardial infarction: experience in a rural-based helicopter medical service. *Eur J Emerg Med*. 2015;22:273–278. DOI: 10.1097/MEJ.0000000000000149.