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

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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...
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. 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. 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.

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. This regionalized system of prehospital triage and acute care has been shown to reduce delays to PCI and improve patient outcomes. 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. EMS times are important process measures for optimizing systems of STEMI care. 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. 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. 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. with standard EMS time reporting (≤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. 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 co-variate 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

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**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.
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 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 |

(Continued)
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.

| Table 2. Frequency of EMS Cardiac Care for Patients With Suspected ACS, Overall and by Urbanicity |
|-------------------------------------------------------------|----------|-----------------|-----------------|
| EMS cardiac care measures                        | Overall (N=4667) | 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.

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. 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.

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. 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. 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, 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. 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* |
|-------------------------------------------------|----------------------------------|-------------------------------------|---------------------|
| Age group, y                                     | Freq. (%) | OR  | 95% CI  | Freq. (%) | OR  | 95% CI  |                      |
| 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. 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 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.

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. As observed in our prior national study of EMS times for patients experiencing chest pain, 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, 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. 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. 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. 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. 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\textsuperscript{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-representation 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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