

Elapsed Time in Emergency Medical Services for Patients With Cardiac Complaints

Are Some Patients at Greater Risk for Delay?

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Background—In patients with a major cardiac event, the first priority is to minimize time to treatment. For many patients, first contact with the health system is through emergency medical services (EMS). We set out to identify patient-level and neighborhood-level factors that were associated with elapsed time in EMS.

Methods and Results—A retrospective cohort study was conducted in 10 municipalities in Dallas County, Tex, from January 1 through December 31, 2004. The data set included 5887 patients with suspected cardiac-related symptoms. The region was served by 29 hospitals and 98 EMS depots. Multivariate models included measures of distance traveled, time of day, day of week, and patient and neighborhood characteristics. The main outcomes were elapsed time in EMS (continuous; in minutes) and delay in EMS (dichotomous; >15 minutes beyond median elapsed time). We found positive associations between patient characteristics and both average elapsed time and delay in EMS care. Variation in average elapsed time was not large enough to be clinically meaningful. However, approximately 11% (n=647) of patients were delayed \geq 15 minutes. Women were more likely to be delayed (adjusted odds ratio, 1.52; 95% confidence interval, 1.32 to 1.74), and this association did not change after adjusting for other characteristics, including neighborhood socioeconomic composition.

Conclusions—Compared with otherwise similar men, women have 50% greater odds of being delayed in the EMS setting. The determinants of delay should be a special focus of EMS studies in which time to treatment is a priority. (*Circ Cardiovasc Qual Outcomes*. 2009;2:9-15.)

Key Words: heart diseases ■ population ■ patients ■ women

For patients with a major cardiac event, the first priority is to minimize time to treatment.^{1,2} Although elapsed time from symptom onset to definitive care is the primary concern, most effort is focused currently on reducing elapsed time from hospital arrival (“door time”) to treatment.³ Door-to-treatment time is a viable target for reduction because it is reliably recorded in hospital administrative data and is most often managed within a single institution.

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To minimize overall time to treatment, a new focus should be directed at the time spent before hospital arrival, including elapsed time in emergency medical services (EMS). Approximately a quarter of patients with chest pain⁴ and half of the patients with myocardial infarction⁵ arrive at the hospital via

EMS. Much could be gained from a new focus on elapsed time in the EMS setting.⁶ Recent development in the collection of administrative data from EMS systems⁷ has made the time segment from the 911 call to hospital arrival an emerging target for study and possible intervention.

The goal of this study was to identify patient and neighborhood characteristics that were associated with time spent in EMS among patients with cardiac complaints. We evaluated the associations between patient-level and neighborhood-level factors and both average elapsed time and delays in EMS, adjusting for geographic and temporal characteristics.

Methods

Our study population was comprised of adult residents of 10 municipalities within Dallas County, Tex, with potential cardiac

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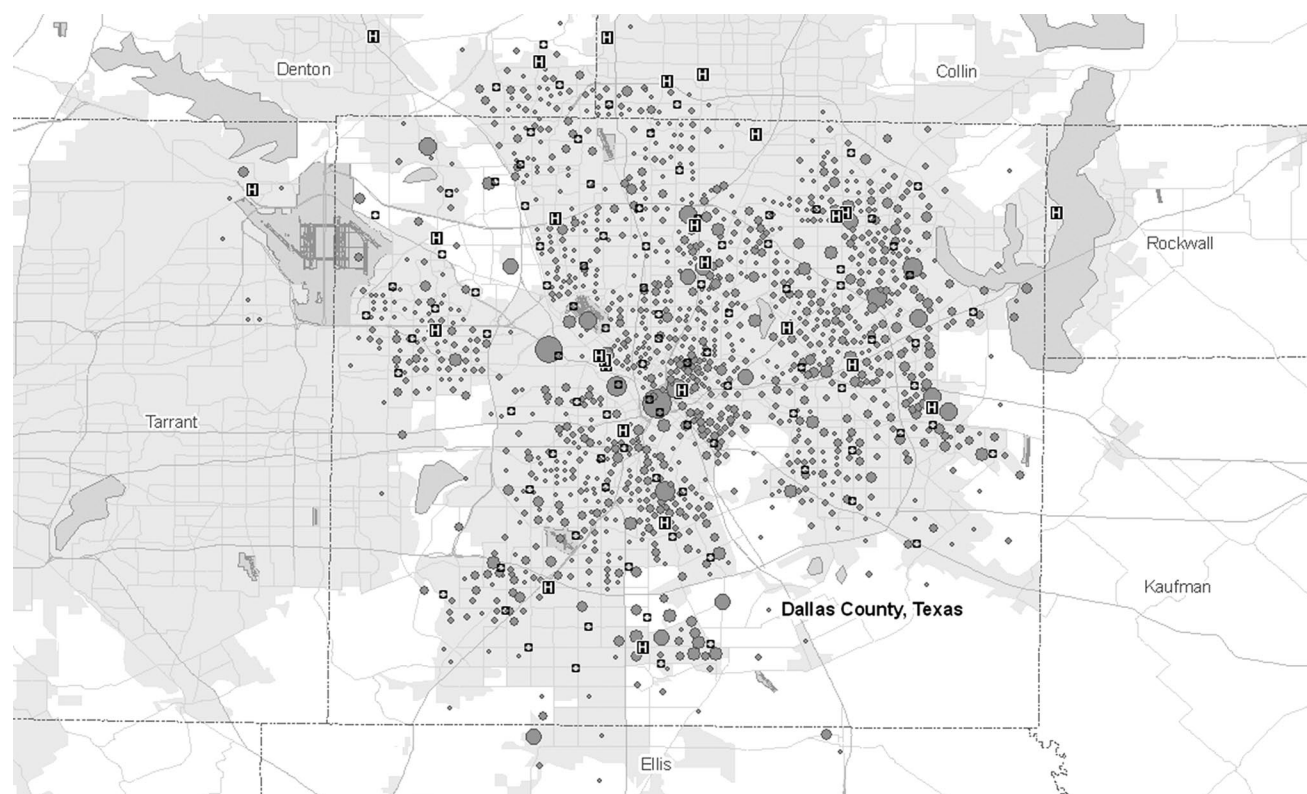


Figure 1. Geographic distribution of hospitals, firehouses, and patients with suspected cardiac symptoms who called 911 in 2004. Hospitals are represented by an H. Firehouses with EMS facilities are represented by a red cross. Patient calls ($n=5887$) are represented by shaded circles and are scaled in size to represent the number of calls, ranging from 1 to 97 calls from any single census block group.

symptoms who made a call to 911 from January 1 through December 31, 2004. This region (Figure) is racially and linguistically diverse, with urban, suburban, and rural districts bounded on 3 sides by sparsely populated counties and on its fourth side by Dallas-Ft Worth airport. These features make the Dallas County EMS system ideal, because the system and the hospitals it serves are contained within the same boundaries, reducing the potential for confounding from unmeasured geographic, population, and health system characteristics lying beyond the system.

The data were compiled from EMS “run sheets” and included patient clinical and demographic characteristics; date, time, and location of emergency calls; vehicle response times, on-scene times, and transport times; and hospital location and treatment capability. The patient’s point of origin was represented by the geographic centroid of the census block group from which the call was made. We used geographic information system software to construct a model of the population, geography, and provider characteristics of Dallas County. The model incorporated US Census data for each of the 1463 census block groups within the 10 municipalities and the straight-line distance between each block group and all emergency providers. The geographic area under study (Figure) is served by 29 hospitals with emergency departments and 98 fire stations with EMS depots.

The first outcome of interest was elapsed time in EMS, measured in 3 segments and rounded to the nearest minute: (1) response time, or elapsed time from patient call to scene arrival, (2) on-scene time, or elapsed time from scene arrival to scene departure, and (3) transport time, or elapsed time from scene departure to hospital arrival. The main analysis combined all 3 segments. A second outcome of interest was delays of 15 minutes beyond median total elapsed time in EMS care. In patients with myocardial infarction, starting reperfusion treatment within 60 minutes of symptom onset is known to prevent irreversible damage to the myocardium,¹ and additional increments of 15 minutes up to 5 hours have been shown

to be predictive of the size of infarct.² Unnecessary delays of 15 minutes or more could, therefore, be harmful to patients with an existing or evolving major cardiac event. We evaluated the group of patients who were in EMS care at least 15 minutes longer than the median patient.

Patient-Level Data

The initial data set included 7567 calls made to 911 by patients with suspected cardiac-related symptoms. Calls that did not result in delivery to a hospital ($n=1394$) were not of interest in this study and were therefore excluded from the analysis. Calls that were missing a time measurement before or at hospital delivery were dropped from the analysis ($n=187$), accounting for fewer than 2.5% of all calls in the initial data set. We excluded patients with excessive elapsed time measurements (more than 1 hour from firehouse to scene, more than 2 hours on scene, or more than 2 hours from scene to hospital) because of the probability that such measurements were made in error ($n=68$). We also excluded patients younger than 18 years ($n=51$) because of the low probability that they experienced an acute coronary syndrome. The final data set included 5887 calls.

Before the analysis, we adjusted for typical shortcomings in observational data by using 2 widely accepted procedures. First, we imputed values for missing observations of age in 16% of patients. Following the approach detailed by Little and Rubin⁸ and adapted by Schafer,⁹ we used a Markov-Chain Monte-Carlo simulation for nonmonotone missing variables to multiply impute the missing values. Ten complete data sets were created. Second, we used an inverse propensity score-weighting procedure described by Lunceford and Davidian¹⁰ to correct for baseline imbalances between racial and ethnic groups. We estimated a propensity score model of the probability that the patient was white, conditional on all measured patient and neighborhood characteristics, excluding the outcomes of interest. The inverse of this propensity score was applied as a weight to make racial and ethnic groups similar in baseline measures. To

confirm weighted balance on these measures, we ran χ^2 tests on categorical variables and a standardized difference estimate (Cohen d) on continuous variables.

Neighborhood-Level Data

Neighborhood socioeconomic data were drawn from the 2000 US Census at the block group level. We included the percent of residents who were white, percent foreign born, and percent living under 200% of the federal poverty level and population density.

Distance traveled in the first segment, from firehouse to scene, was estimated along a straight line from the nearest firehouse to the geographic centroid of the patient’s block group. Distance estimates in the third segment were computed along the straight line from the patient’s block group to the observed arrival hospital. Both straight-line and rectilinear distances are highly correlated with road network distances in urban, semiurban, and suburban areas; however, straight-line estimates are better as population density approaches rurality,¹¹ as it does in parts of the Dallas County.

Analytic Models

To identify predictors of average elapsed time in EMS, we fit 4 successive linear regression models for each time segment and for total elapsed time. The initial model for each elapsed time measure included travel distance alone. In successive models, we added day of the week and time of day, and patient and neighborhood characteristics. To identify predictors of delay, we estimated an additional multiple logistic regression with 15-minute delay as the outcome of interest. We adjusted for distance, onset time, patient vitals, age, race, and neighborhood socioeconomic composition. We also included a dummy variable for bypassing a close hospital in favor of a distant hospital with a cardiac catheterization laboratory that was open and staffed at the time of hospital arrival.

Seventeen models were thus estimated within each of the 10 imputed data sets. For every model, observations were weighted using the inverse propensity for being of white race, continuous variables were centered on their means, and neighborhood characteristics were adjusted to account for differences of one standard deviation. We combined models across the 10 data sets by taking the average of coefficients and standard errors and inflating the errors with the between-model variation.⁸

The authors had full access to the data and take responsibility for its integrity. All authors have read and agree to the article as written. The research protocol was deemed exempt by the institutional review boards at Tufts Medical Center and University of Texas–Southwestern.

Results

After exclusions, 5887 calls were included. Table 1 presents baseline characteristics of the cohort. Average age was 57.9 (standard deviation, 17.7) years. Women comprised 50.8% of the cohort, and people of white race comprised 49.9%. After weights were applied ($c=0.76$), there were no significant differences between white and nonwhite patients on measured covariates.

The Average Patient

Our “as-the-crow-flies” estimate of travel distance in segment one (firehouse to scene) averaged 0.9 miles (interquartile range, 0.6 to 1.2) and the average elapsed time was 5.7 minutes (4.0 to 6.0). Average time spent in segment 2 (on-scene) was 19.9 minutes (15.0 to 24.0). In time segment 3 (scene to hospital), average distance was 4.1 miles (1.9 to 5.4) and average elapsed time was 10.3 minutes (5.0 to 13.0). Total distance was 5.0 miles (2.73 to 6.4) and average elapsed time was 35.9 minutes (28.0 to 41.0). Median elapsed time in EMS was 34 minutes.

Table 1. Baseline Characteristics of the Cohort

Covariates	N	Value
Distance characteristics, miles		
EMS depot to scene	5650	0.9 (0.45)
Scene to hospital	5321	4.05 (3.3)
Time characteristics		
Rush hour, morning	5887	8.7
Rush hour, evening	5887	8.5
Weekday	5887	75.3
Patient characteristics		
Age, years	4556	57.9 (17.7)
Female	5887	50.8
Race/ethnicity	5887	...
White	...	49.9
Black	...	32.1
Latin/Hispanic	...	8.8
Asian/Pacific Islander	...	2.6
Native American	...	2.4
Other	...	1.2
Unknown	...	3.0
Diastolic blood pressure, mm Hg	5166	89.3 (21.3)
Systolic blood pressure, mm Hg	5370	148.9 (34.2)
Pulse, beats/min	5824	87.1 (41.1)
Respiratory rate, breaths/min	5716	18.0 (6.7)
Neighborhood characteristics		
Population density, ×1000 residents/square mile	5865	5.3 (2.8)
Race, % white	5865	43.9 (30.4)
Birthplace, % foreign-born	5865	16.4 (15.5)
Income, % households <200% FPL	5865	35.6 (22.7)

Data are presented as % or mean (SD). FPL indicated federal poverty level.

Table 2 presents the results of the most comprehensive analytic model, including all distance, time, and patient and neighborhood characteristics. Over total elapsed time, each mile traveled to and from the scene contributed 1.3 minutes. Patients who were transported during evening rush hour spent a little more than 2 additional minutes in EMS care. Blacks and whites, the 2 largest race groups, had nearly identical transport times on average. Asian/Pacific Islanders and Native Americans spent 2.9 and 3.0 minutes longer, respectively, than did whites. Women were delivered to the hospital 2.3 minutes slower on average than men. Characteristics of the neighborhood from which a patient called did not make a statistically significant contribution to total elapsed time.

Delayed Patients

Of 5887 patient calls, 647 (11.0%) resulted in delays of 15 minutes or more (≥ 49 minutes) beyond median elapsed time (34 minutes). Of these 647, average elapsed time was 58.6 minutes and average distance was 7.8 miles. All of the delay was attributable to extra time spent in segments 2 and 3 (on-scene and transport). In segment 1 (response), delayed patients traveled 1 mile in 6.5 minutes, roughly the same as average patients. EMS personnel spent 28.3 minutes on

Table 2. Time Spent in EMS Transport

Covariates	Elapsed Time, Minutes			
	Segment 1: Response (SE)	Segment 2: On-Scene (SE)	Segment 3: Transport (SE)	Total: EMS Depot to Hospital (SE)
Distance				
EMS Depot to scene	0.92 (0.11)*	1.33 (0.34)*
Scene to hospital	1.21 (0.03)*	1.33 (0.05)*
Time				
Rush hour, morning	0.40 (0.17)†	...	-0.15 (0.35)	0.57 (0.48)
Rush hour, evening	0.01 (0.17)	...	1.37 (0.34)*	2.01 (0.50)*
Weekday	0.04 (0.11)	0.33 (0.23)	0.31 (0.23)	0.56 (0.33)
Patient characteristics				
Black	-0.01 (0.11)	-0.25 (0.24)	0.38 (0.24)	0.08 (0.34)
Latin/Hispanic	0.65 (0.17)*	-0.60 (0.35)	-0.05 (0.33)	0.10 (0.48)
Asian/Pacific Islander	-0.95 (0.32)†	2.76 (0.67)*	-0.97 (0.64)	2.88 (0.91)‡
Native American	-0.48 (0.29)	2.36 (0.61)*	1.17 (0.58)†	3.03 (0.84)*
Other race (not white/other)	-1.05 (0.35)‡	-0.25 (0.78)	-0.37 (0.79)	-1.72 (1.16)
Unknown race	-0.40 (0.22)	3.44 (0.48)*	0.52 (0.49)	0.03 (0.01)*
Age, years	-0.01 (0.00)†	0.03 (0.01)*	0.01 (0.01)	0.03 (0.01)†
Female	-0.23 (0.10)†	-1.51 (0.20)*	0.57 (0.20)	-2.30 (0.28)*
Neighborhood characteristics				
Population density, ×1000 residents/square mile	-0.10 (0.05)†	0.27 (0.11)†	-0.07 (0.10)	0.26 (0.15)
Race, % white	0.02 (0.07)	0.68 (0.16)*	-0.45 (0.16)‡	0.36 (0.22)
Birthplace, % foreign-born	-0.01 (0.06)	0.16 (0.12)	-0.16 (0.11)	0.01 (0.17)
Income, % households <200% FPL	0.18 (0.07)†	-0.21 (0.15)	-0.18 (0.15)	-0.10 (0.21)

All estimates are adjusted for patient vital statistics, including blood pressure, pulse, and respiratory rate. White race and male are reference categories. Continuous variables were centered on their mean value. Coefficients on neighborhood-level covariates represent the change in outcome per 1 SD from the mean. FPL indicates federal poverty level.

* $P < 0.001$; † $P < 0.05$; ‡ $P < 0.01$.

scene, approximately 9 minutes longer than average. In segment 3, patients traveled nearly 7 miles in 27.7 minutes, or 13.4 minutes longer than average.

Table 3 presents ratios for the odds of delay. Women had significantly higher odds (odds ratio, 1.52; 95% CI, 1.32 to 1.74) of being in the delay group. Each additional mile traveled gave patients 9% to 46% greater odds of being in the delay group. Traveling during evening rush hour, bypassing a local hospital, being Asian/Pacific Islander, Native American, or of unknown race also increased the odds of being delayed whereas being of "other" race decreased the odds.

Being from a more densely populated neighborhood modestly increased the odds of delay. Being from a white neighborhood appeared at first to contribute to delay, but this effect was not monotonic. We assessed separately the adjusted odds of delay for patients from the 4 quartiles of white concentration. Neighborhoods in the third quartile were more likely than all others to be delayed, and this effect was strong enough to persist over the continuous measure.

Discussion

Our study of patient and neighborhood characteristics associated with elapsed time in EMS in 10 municipalities in Dallas County, Tex, including 29 hospitals and 98 EMS

stations over a 1-year period, showed that women were 50% more likely than men to be delayed while in EMS care. This difference remained even after adjusting for day of week and time of day of symptom onset, distance, age, race, vital signs as an indicator of clinical severity, and neighborhood socioeconomic composition.

Our primary conclusion is consistent with a large body of research into gender disparities in acute coronary syndromes. Women with myocardial infarction are more likely to delay seeking emergency medical care,^{12,13} they present with higher risk,¹⁴ are less likely to receive percutaneous coronary intervention,¹⁵ have longer door-to-balloon times,¹⁶ and are more likely to die before discharge, even after controlling for older age and higher severity.¹⁷ Further explanation as to whether gender differences in presentation, care, and outcomes are the result of bias or biology is needed.¹⁸ Our results suggest that this need may extend to the EMS setting.

Although our analysis does not reveal *why* women were more likely to be delayed, previous research suggests a plausible explanation: symptom presentation in women with cardiac disease differs from that of men¹⁹ and a coronary event may not be recognized as readily by the patient²⁰ or by EMS personnel. Inappropriate delays may occur because there is less certainty of cardiac involvement, because more

Table 3. Odds of Being Delayed in EMS Care

Covariates	Odds of Delay (95% CI)
Distance characteristics	
EMS depot to scene	1.26 (1.09–1.46)
Scene to hospital	1.22 (1.20–1.25)
Bypass	1.81 (1.53–2.15)
Time characteristics	
Rush hour, morning	1.18 (0.93–1.49)
Rush hour, evening	1.97 (1.59–2.43)
Weekday	1.04 (0.87–1.24)
Patient characteristics	
Black	1.15 (0.97–1.35)
Latin/Hispanic	1.02 (0.81–1.31)
Asian/Pacific Islander	1.89 (1.29–2.78)
Native American	1.60 (1.11–2.29)
Other race (not white/other)	0.35 (0.15–0.79)
Unknown race	1.74 (1.29–2.35)
Age, years	1.00 (1.00–1.01)
Female	1.52 (1.32–1.74)
Neighborhood characteristics	
Population density, ×1000 residents/square mile	1.11 (1.03–1.19)
Race, % white	1.16 (1.04–1.29)
Birthplace, % foreign-born	0.95 (0.88–1.04)
Income, % households <200% FPL	1.04 (0.93–1.15)

Delay was defined as >15 minutes beyond the median elapsed time. All estimates are adjusted for patient vital statistics, including blood pressure, pulse, and respiratory rate. White race and male are reference categories. Continuous variables were centered on their mean value. Coefficients on neighborhood-level covariates represent the change in outcome per 1 SD from the mean. FPL indicates federal poverty level.

time is spent diagnosing the condition, because the patient’s condition may not be seen as emergent, or as the result of some combination of these factors.

Variation in average elapsed time was too small to be clinically meaningful. This may be explained in part by the fact that average total elapsed time in EMS is just not long enough to allow for much clinically meaningful variation. A close look at the Figure shows that firehouses cover the region in a nearly uniform geographic distribution, which may be especially influential in maintaining brief and uniform response times in segment one (911 call to scene arrival). In this segment, 50% of all calls result in a response time of between 4 and 6 minutes. Interpatient variation begins more substantially in segment 2 (on-scene) and continues in segment 3 (scene to hospital), suggesting that something other than the distribution of firehouses is at play. In regions that manage similarly uniform geographic distribution of EMS depots, we would not expect to find meaningful average variation by patient or neighborhood characteristics.

The results also suggest that aside from gender, other patient characteristics (race and age) influenced average elapsed time and delays, whereas neighborhood socioeconomic composition had no meaningful effect. However, in all variables other than gender, variation in the odds of delay

involved few individuals. For Asian/Pacific Islanders, Native Americans, and people of unknown race, the odds of being delayed were statistically significant but the number of patients affected was small (20, 18, and 22 individuals, respectively, were delayed for reasons other than bypassing a hospital).

Our second conclusion is that long delays should be a special focus of research in the EMS setting. In our study, women arrived at the hospital, on average, just more than 2.3 minutes later than men, not long enough to be clinically meaningful. However, women were also 50% more likely to be delayed. By dichotomizing the time variable and looking at the extreme of the distribution, we were able to identify variables that had an important effect on delays. Had we concentrated only on average elapsed time and not also on delays, our study could have obscured a significant and meaningful gender disparity. A previous study of elapsed time in EMS for patients with stroke,²¹ for example, found variation in average elapsed time to hospital arrival, including a 5-minute lag for black compared to white patients after adjusting for age, distance traveled, and area poverty. As in our study, this lag was not large enough to be clinically meaningful. However, there was evidence of potentially hazardous delay for some patients in the study. Median and maximum elapsed time from 911 to hospital arrival were 28 and >90 minutes, respectively, representing at least a 62-minute gap between the typical and most delayed patients, but this study did not evaluate the gap for evidence of disparities, despite the signal of slower average elapsed time for black patients. We suggest that the determinants of delay should be included in all EMS studies where time to treatment is a priority.

Our findings have several implications for future research. Our primary finding that women with cardiac-related complaints are at greater risk for delay in EMS than are men should be tested in a range of settings. Similarly, elapsed time in EMS should be studied in other clinical domains. As already discussed, the determinants of delay should be a special focus of EMS studies where time to treatment is a priority. Finally, qualitative research should be directed at understanding why delays occur. To make such research possible, EMS systems must continue to make improvements in the collection, maintenance, and reporting of patient data. Both qualitative and quantitative data are needed on patient experiences from 911 through hospital discharge. Efforts to establish national standards for EMS run sheet documentation are underway through the National EMS Information System and its Technical Assistance Center⁷; National EMS Information System–related programs should remain a top priority for funding and research support until EMS systems meet these standards. EMS systems must also continue to test and evaluate methods to improve quality and reduce elapsed time to hospital arrival. Results from several regional EMS pilot projects around the United States suggest there is unmet potential in both of these domains. These have included the introduction of electrocardiograms and hospital prenotification into the EMS setting.^{22–26} Decision aids for triage of patients with acute cardiac ischemia and ST-elevation myocardial infarction have been implemented safely and effec-

tively in the emergency department setting,^{27–29} and calls have been growing for their use in EMS.^{23,30,31} The American Heart Association's nascent Mission: Lifeline program is designed to assess and improve EMS effectiveness as part of a systemwide quality improvement program for the care of patients with ST-elevation myocardial infarction.³²

This study faced some limitations. Compared with US Census data, Latin/Hispanic ethnicity was underrepresented and white race was overrepresented in our data set, probably as a result of misclassification. Improved methods of collecting patient data in the EMS setting might lead to new observations about associations between race and time to treatment. Second, we studied elapsed time in EMS in only one region. We selected the Dallas County for its size, diversity, and composition of urban, suburban, and rural districts, but the primary advantage of this setting was its self-contained EMS and hospital systems, allowing us to estimate effects in an area with little confounding at the borders. Third, our analytic models tested for multiple potential associations with delay, increasing the probability of a spurious false-positive result. However, the association between gender and delay was both robust to adjustment and monotonic across the distribution of elapsed time. Furthermore, it is consistent with a large body of previous research on gender in cardiac care. We believe our analysis and results make a strong case for the existence of a gender disparity in the EMS setting.

In summary, we found that women with cardiac complaints were more likely to be delayed in EMS, even after adjusting for distance, onset time, patient vitals, age, race, and neighborhood. This result would have been missed if we focused solely on average elapsed time to the exclusion of delays. Delays should be a special focus of research in the EMS setting. Future research should examine delay in other geographic settings and clinical domains, explore why delay occurs, and evaluate interventions for eliminating unnecessary delay. Continued efforts to improve the collection, maintenance, and reporting of EMS data; to improve quality; and to reduce elapsed time from 911 to hospital arrival should be a top priority.

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Disclosures

None.

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CLINICAL PERSPECTIVE

This study of elapsed time in emergency medical services (EMS) in 10 municipalities in Dallas County, Texas including 29 hospitals and 98 EMS stations over a 1-year period, showed that women were 50% more likely than men to be delayed while in EMS care. This difference remained after adjusting for day of week and time of day of symptom onset, EMS transport distance, age, race, vital signs as an indicator of clinical severity, and neighborhood socioeconomic composition. This result would have been missed if the authors focused solely on average elapsed time, to the exclusion of measuring and testing associations with delays in EMS. Although the analysis does not reveal why women were more likely to be delayed, previous research suggests a plausible explanation: symptom presentation in women with cardiac disease differs from that of men, and a coronary event may not be recognized as readily by the patient or by EMS personnel. Inappropriate delays may occur because there is less certainty of cardiac involvement, because more time is spent diagnosing the condition, because the patient's condition may not be seen as emergent, or as the result of some combination of these factors. Delays should be a special focus of research in the EMS setting. Future research should examine delays in other geographic settings and clinical domains, explore why delays occurs, and evaluate interventions for eliminating unnecessary delays.