OPEN

Association Between System Factors and Acute Myocardial Infarction Mortality

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Objectives: We conducted a cross-sectional study to assess the association between healthcare system factors and death from acute myocardial infarction (AMI), in terms of access (distance to the hospital, mode of transportation), availability (emergency medical services, hospitals), and capability (emergency medical services' 12-lead electrocardiogram capability, continuous percutaneous coronary intervention [PCI] and cardiothoracic surgical services), after accounting for individual and environmental factors.

Methods: Data on 14,663 deaths (in-hospital and out of hospital) and live hospital discharges as a result of AMI for 2012 and 2013 among Arkansas residents were obtained from the Arkansas Department of Health. A mixed-effects logistic regression model was used to account for nesting, in which an individual was nested within either a county or a hospital to evaluate the association of system factors with death from AMI.

Results: Deaths from AMI were significantly associated with two system factors: a 9.2% increase in the odds of deaths from AMI for every 10-mi increase in distance to the nearest hospital (odds ratio 1.092, 95% confidence interval 1.009–1.181) and a 64% increase in the odds of death from AMI among hospitals without continuous PCI capability (odds ratio 1.64, 95% confidence interval 1.15–2.34), after adjusting for individual and environmental factors.

Conclusions: A higher risk of AMI deaths was associated with healthcare system factors, especially distance to nearest hospital, and hospitals' continuous PCI capability, even after adjusting for individual and environmental factors. A coordinated system of care approaches that mitigates gaps in these system factors may prevent death from AMI.

Key Words: acute myocardial infarction, healthcare system factors, hospitals, mortality, percutaneous coronary intervention

Every year >115,000 people in the United States die of acute myocardial infarction (AMI).[1] Early treatment with percutaneous coronary intervention (PCI) during the "golden hour" (the first 60–90 minutes after blockage occurs) has been shown to avert deaths caused by AMI, especially ST-elevated MI.[2–5] If the time from first medical contact to PCI is anticipated to be >120 minutes, then thrombolytic therapy (with a clot-busting drug) at the closest non-PCI hospital is recommended to prevent deaths from AMI.[4] Early treatment has been shown to decrease death associated with AMI by as much as 37%.[2–5]

Individuals live in the context of environment and healthcare systems in communities. Environmental factors such as access to healthy food and venues for physical activity are important factors that affect diet and physical activity in individuals living in the community.[6–9] Furthermore, contextual factors such as education and poverty in the community or neighborhood contribute to the health status of its residents.[10,11] Healthcare system (hereafter referred to as "system") factors such as access (distance to hospital, mode of transportation) and availability of emergency medical services (EMS) and hospitals,

Key Points

- Every year >115,000 people in the United States die of acute myocardial infarction (AMI).
- Healthcare system factors such as access (distance to nearest hospital, mode of transportation) and availability of emergency medical services and hospitals, particularly hospitals capable of performing percutaneous coronary intervention, could influence AMI mortality.
- A higher risk of death from AMI was associated with healthcare system factors, especially distance to the nearest hospital, and hospitals' continuous percutaneous coronary intervention capability, even after adjusting for individual and environmental factors.
- A coordinated system of care approach that mitigates gaps in these system factors may prevent death from AMI.

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This work was supported in part by award no. 1U48DP005005 from the Centers for Disease Control and Prevention. The content is solely the responsibility of the authors and does not necessarily represent the official views of the Arkansas Department of Health or the Centers for Disease Control and Prevention.

The authors did not report any financial relationships or conflicts of interest.

Accepted March 20, 2018.

0038-4348/0–2000/111-556

DOI: 10.14423/SMJ.0000000000000853

particularly hospitals capable of performing PCI, could influence AMI mortality.[2,12–16] In addition, the 12-lead electrocardiogram (EKG) capability of EMS, the capacity of hospitals to provide continuous PCI coverage, and the availability of cardiothoracic surgical services for patients with complex AMI are critical.[3–5] These system factors, along with individual and environmental factors, influence the utilization of emergency care for AMI, and hence AMI mortality. To date, studies have evaluated the influence of these factors to AMI mortality individually without accounting for all of them together. In this investigation, we evaluated the association of system factors in terms of access, availability, and capability, with AMI mortality while controlling for individual and environmental factors.

Methods

We conducted a retrospective cross-sectional study to assess the association of system factors with AMI mortality after accounting for individual and environmental factors. The overall research question was "Are system-level factors associated with AMI mortality after adjusting for individual and environmental factors?" To address this question, we assessed two component questions: are system-level factors such as EMS availability, hospital availability, and hospital capability (PCI capability, continuous PCI coverage, cardiothoracic surgical capability) associated with AMI mortality, after adjusting for individual and environmental factors, and are hospital characteristics (type of hospital [size, ownership]), including its capability and readiness (participation in a time-sensitive response system such as a trauma system), associated with AMI mortality among individuals who are hospitalized, after adjusting for individual and environmental factors?

Data Abstraction

Individual death records for 2012 and 2013 that coded AMI as an underlying cause of death using *International Classification of Diseases*, *Tenth Revision* codes I21 and I22 were obtained from the Vital Statistics Section of the Arkansas Department of Health (ADH). Similarly, individual hospital records for 2012 and 2013 for all patients who were discharged alive with AMI as a principal diagnosis, coded using *International Classification of Diseases*, *Ninth Revision* code 410, were obtained from the Hospital Discharge Data System Section of the ADH. Because the place of death (eg, hospital, home) also is collected in death records, we did not obtain hospital discharges with disposition of AMI deaths to avoid duplication. Distance to the nearest hospital was calculated from an individual's residence as provided on either the death or hospital discharge record.

Data on environmental and system-level factors in Arkansas were obtained from multiple sources. Data were captured for 2012 or 2013 so that independent variables of interest and control variables describe to the extent possible the same period (2012–2013) in which events occurred. Data captured at the county level were matched to the county within which the individual resided at the time of the event. Table 1 describes the data abstracted, including the study variables, data values, data source, and time frame.

Data to characterize environmental (contextual) factors (eg, education, poverty) would be available ideally at the individual level; however, neither Arkansas death certificates nor hospital discharge records capture these variables. These variables therefore are defined at the county level and were included to characterize the context within which the event occurs, rather than individual characteristics or behaviors. Information on county populations, such as educational attainment and poverty levels, were obtained from the American Community Survey.[17] County-specific information on the prevalence of demographic characteristics was obtained from the Arkansas Behavioral Risk Factor Surveillance System survey. The Behavioral Risk Factor Surveillance System is a telephone survey that tracks the health risks of Americans aged 18 years and older (www.cdc.brfss.gov). The contextual health characteristics obtained for each county included the percentage of county residents who were overweight or obese (body mass index calculated from self-reported weight and height), current smokers, and/or physically inactive; self-reported a diagnosis of coronary heart disease, hypertension, diabetes mellitus, hyperlipidemia, and/or depressive symptoms; were aware of AMI signs and symptoms; and expressed an intent to use the 9-1-1 system to seek care. Data on system factors such as the availability of EMS and hospitals, especially PCI-capable hospitals, and the continuous availability of PCI in PCI-capable hospitals at the county level were obtained from the ADH, the Arkansas Hospital Association, and the American Heart Association. ADH is the licensing authority for all EMS agencies and hospitals in the state. ADH has information on the availability of EMS in each county, as well as hospital characteristics such as hospital size (categorized as large, medium, or small based on number of beds), ownership (private, not for profit, public), and location of each hospital. The American Heart Association collects information on the PCI capability of each hospital, the availability of continuous PCI coverage, and the presence of cardiothoracic surgical services in the hospital. Information on EMS capabilities such as 12-lead EKG was not available. The newly compiled dataset was used to assess the association of system factors to AMI mortality in Arkansas. The University of Arkansas for Medical Sciences institutional review board and the science advisory committee of the ADH approved the study.

Statistical Analysis

Analyses were performed using SAS version 9.3 (SAS Institute, Cary, NC). Data characterizing counties were merged with the base analytic data by county of residence. Data characterizing hospitals were merged with the base analytic data by hospital. Data were assessed for completeness. Frequencies of categorical variables and means and standard deviations for continuous variables were calculated to describe the study

Table 1. List of study variables, their data values, sources, and time frame

	Data values (coded categories)	Data source	Time frame
Variables			
Event	Numerical identifier	DC and HDDS	2012, 2013
Died (0/1)	0 = alive, 1 = died	DC and HDDS	2012, 2013
Individual level			
Age	Age at last birthday, y	DC and HDDS	2012, 2013
Sex	1 = male, 2 = female	DC and HDDS	2012, 2013
Race	1 = white, 2 = African American, 3 = other	DC and HDDS	2012, 2013
Place of death	1 = inpatient, 2 = emergency department/outpatient, 3 = dead on arrival, 4 = decedent's home, 5 = hospice facility, 6 = nursing facility/long-term care facility, 6 = other	DC and HDDS	2012, 2013
Place of residence	Number (house/apartment no.), street, city, or county	DC and HDDS	2012, 2013
Distance to nearest hospital	In mi	Calculated from place of residence to nearest hospital	2012, 2013
Environmental (contextual)			
County education	% with less than high school education	ACS	2009–2013
County poverty	% living below federal poverty level	ACS	2009–2013
County uninsured	% of adults who report being uninsured	BRFSS	2013
County obesity	% of adults who report BMI ≥30	BRFSS	2013
County not consuming recommended fruits/vegetables	% of adults who report not consuming recommended fruits and vegetables	BRFSS	2013
County no leisure time physical activity	% of adults who report no leisure time physical activity	BRFSS	2013
County smoking	% of adults who report to be current smokers	BRFSS	2013
County coronary heart disease or angina	% of adults who report coronary heart disease or angina	BRFSS	2013
County diabetes mellitus	% of adults who report diabetes mellitus	BRFSS	2013
County hyperlipidemia	% of adults who report high cholesterol	BRFSS	2013
County depression	% of adults who report depression symptoms	BRFSS	2013
County awareness of AMI signs and symptoms	% of adults who are aware of AMI signs and symptoms	BRFSS	2011
County reaching out to care for AMI	% of adults who intend to call 9-1-1 if experiencing AMI signs and symptoms	BRFSS	2011
System level			
County-licensed EMS agency	No. licensed EMS agencies/1000 population	ADH Health Facilities licensing section	2012
County-licensed hospital	No. licensed hospitals/1000 population	ADH Health Facilities licensing section	2012
County PCI-capable hospital	No. PCI-capable hospitals/1000 population	AHA	2012
County PCI-capable hospital with continuous coverage	No. PCI-capable hospitals with continuous coverage/1000 population	AHA	2012
County PCI-capable hospital with cardiothoracic surgery services	No. PCI-capable hospitals with cardiothoracic surgery services/1000 population	AHA	2012
Hospital characteristics			
Size of hospital	1 = large, 2 = medium, 3 = small	ADH Health Systems licensing data	2013
Type of ownership	1 = public, 2 = not for profit, 3 = private	ADH Health Systems licensing data	2013
Level of trauma system	0 = undesignated; 1–4 levels, with 1 = most prepared and 4 = least prepared	ADH's trauma section	2012

ACS, American Community Survey; ADH, Arkansas Department of Health; AHA, American Heart Association; AMI, acute myocardial infarction; BMI, body mass index; BRFSS, Behavioral Risk Factor Surveillance System survey; DC, death certificate; EMS, emergency medical services; HDDS, Hospital Discharge Data System; PCI, percutaneous coronary intervention.

sample. In addition, correlation and associations between key variables were assessed. Mixed-effects logistic regressions were used to address the two component questions that evaluated the association of system factors and hospital characteristics with AMI mortality after adjusting for individual and environmental factors. These analyses accounted for nesting, in which an individual was nested either within a county or within a hospital.

Results

There were a total of 15,514 AMI events among Arkansas residents during 2012 and 2013. Thirty percent (n = 4613) of these events resulted in death, and the remainder resulted in patients being discharged alive from a hospital. The majority of AMI deaths and live hospital discharges were among either whites or African Americans. We excluded other races (n = 517; 3% of the total sample) because of the small numbers. We also excluded 334 deaths from AMI and live hospital discharges from 6 Arkansas border counties (Fig. 1) because most residents from these counties use hospitals in neighboring states for their healthcare needs, and we do not have access to their hospital records (personal communication with the Section Chief, Hospital Discharge Data System, Arkansas Department of Health, oral communication, January 14, 2016).

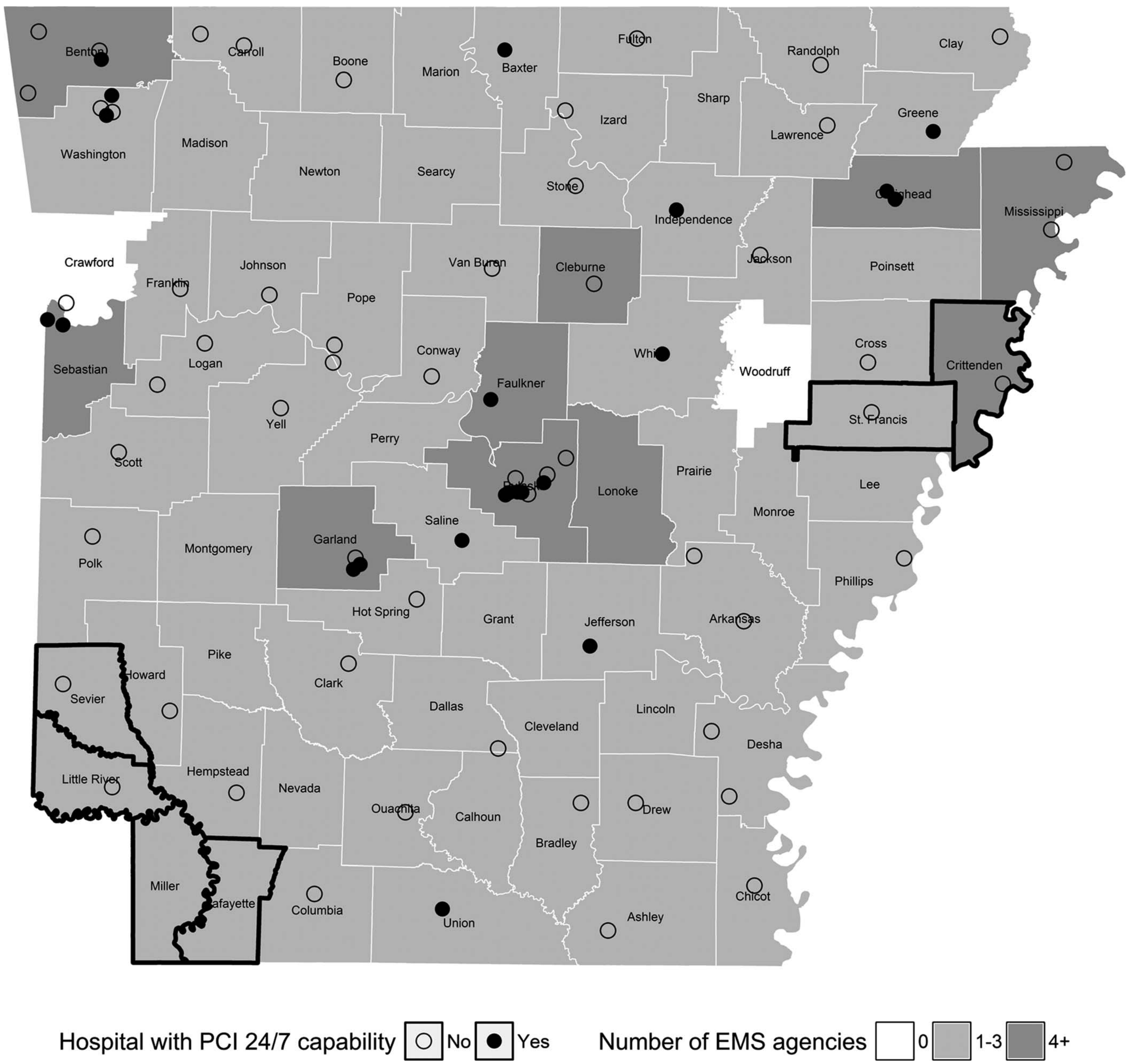

Fig. **Distribution of system factors (EMS, hospitals, and their continuous PCI capability) in Arkansas counties. The 6 border counties (Sevier, Little River, Miller, Lafayette, St Francis, and Crittenden) outlined in bold were excluded from the analyses. EMS, emergency medical services; PCI, percutaneous coronary intervention.**

Table 2. Characteristics of individual, system, and environmental (contextual) factors associated with AMI in analytic and excluded counties of Arkansas, 2012–2013

Characteristics	Analytic sample (N = 14,663)	Excluded sample (n = 334)[a]
Individual		
Age, y (mean age ± SD)	67.7 ± 14.6	71.9 ± 15.8[b]
Sex, %[b]		
Female	40.4	47.3
Male	59.6	52.7
Race, %		
White	90.3	59.3
African American	9.7	40.7
Distance to nearest hospital, mi (mean ± SD)	6.6 ± 6.1	6.8 ± 7.2
Disposition status, %		
Alive	70.3	23.4
Dead	29.7	76.7
System level, mean (range)		
No./1000 population in county		
Licensed EMS agencies	0.07 (0–0.37)	0.11 (0.11–0.12)[b]
Licensed hospitals	0.03 (0–0.16)	0.03 (0.03–0.04)
Continuous PCI-capable hospitals	0.01 (0–0.03)	0.00 (0.00–0.00)[b]
Environmental (contextual), mean (range)		
% Arkansas county adults reporting		
Living below federal poverty line	20.00 (19.9–20.1)	18.6 (17.7–19.4)[b]
No health insurance	21.2 (21.0–21.3)	22.0 (21.8–22.2)
Obesity	33.7 (33.6–33.8)	43.8 (43.2–44.3)[b]
Current smoker	24.9 (24.8–25.0)	25.0 (24.6–25.3)
Coronary heart disease or angina	5.2 (5.1–5.2)	5.4 (5.2–5.6)
Diabetes mellitus	11.2 (11.2–11.3)	15.2 (14.6–15.7)[b]
High cholesterol	42.1 (42.0–42.1)	47.4 (46.8–48.1)[b]
Depressive symptoms	24.3 (24.2–24.4)	20.6 (19.9–21.2)[b]
Recognizing AMI signs and symptoms	43.9 (43.8–43.9)	41.5 (40.5–42.5)[b]
Intent to call 9-1-1 for AMI emergency	85.1 (85.0–85.1)	85.7 (85.3–86.1)[b]

[a]*Arkansas residents from Miller, Lafayette, Little River, Sevier, Crittenden, and St Francis counties.*

[b]*$P < 0.05$.*

AMI, acute myocardial infarction; EMS, emergency medical services; PCI, percutaneous coronary intervention; SD, standard deviation.

The final analytic sample (n = 14,663) was used to assess the association of system factors with AMI mortality. Characteristics of the sample are summarized in Table 2. The mean age of the study population was 67.7 years; the sex was predominantly male (59.6%), and the race was mostly white (90.3%). The average distance to the nearest PCI hospital was 6.6 mi.

Descriptive Analysis

The Figure shows the distribution of EMS agencies and hospitals, especially PCI-capable hospitals, among Arkansas's counties. There were 166 licensed EMS located in 73 of the 75 Arkansas counties. Two Arkansas counties did not have a licensed EMS agency. We did not have information on how many of these services had 12-lead EKG capability. There were 77 licensed general medical/surgical hospitals located in 54 of the 75 Arkansas counties. Twenty-one Arkansas counties did not have a licensed hospital. Arkansas hospitals were categorized by size based on their bed capacity and location. A rural hospital with ≥75 beds, an urban nonteaching hospital with ≥200 beds, and an urban teaching hospital with ≥450 beds are considered large hospitals. A rural hospital with 40 to 74 beds, an urban nonteaching hospital with 100 to 199 beds, and an urban teaching hospital with 250 to 449 beds are considered medium-size hospitals. A rural hospital with 1 to 39 beds, an urban nonteaching hospital with 1 to 99 beds, and an urban teaching hospital with 1 to 249 beds are considered small hospitals. The hospitals were grouped as small (n = 35), medium (n = 18), or large (n = 24) and private (n = 43), not for profit (n = 23), or public (n = 11) based on ownership status. Hospitals were typically small (46%) and privately owned (56%). Of the 77 licensed general medical surgical hospitals, only 22 had PCI capability. The 22 PCI-capable hospitals were located in only 13 of the 75 Arkansas counties. The majority (21 of 22) provided continuous coverage, and 16 had additional cardiothoracic surgical services. Regarding the hospital's level of readiness for time-sensitive conditions such as trauma, slightly less than half (34 of 77 hospitals, 44.2%) were level 4 trauma hospitals; the remainder were designated as levels 1 (n = 2), 2 (n = 3), or 3 (n = 17) or were undesignated (n = 21).

To assess the association between hospital characteristics and AMI mortality, we analyzed 11,458 AMI hospital discharges in Arkansas during the same period. Six percent of these individuals (n = 676) died, whereas the remainder survived and were discharged from the hospital. As before, we excluded other races (n = 424) and 69 AMI hospital discharges from 6 Arkansas border counties. The final analytic sample (N = 10,967; Table 3) was used to assess the association of hospital characteristics with AMI mortality. The sample was relatively older (mean age 66.7 years), predominantly men (59.3%), and white (91.2%).

The correlation among all of the predictor and independent variables was assessed. We found a strong correlation ($r = 0.914$) between number of PCI-capable hospitals per 1000 population in a county and the number of PCI-capable hospitals with continuous coverage per 1000 population in a county. This result was not surprising because 21 of the 22 PCI-capable hospitals in Arkansas provide continuous coverage. Similarly, a moderate correlation ($r = 0.663$) was found between the number of PCI-capable hospitals with continuous coverage and those PCI-capable hospitals with cardiothoracic surgical services per 1000 population in the county. Because of these correlations, only the number of PCI-capable hospitals with continuous coverage per 1000 population in the county was included in the multivariate models.

Table 3. Characteristics of individuals who were discharged with AMI in Arkansas, 2012–2013

Characteristics	Analytic sample (n = 10,967)	Excluded sample (n = 69)[a]
Individual		
Age, y (mean ± SD)	66.7 ± 14.3	71.4 ± 14.0[b]
Sex, %		
Female	40.7	53.6
Male	59.3	46.4
Race, %[b]		
White	91.2	52.2
African American	8.8	47.8
Disposition status, %		
Alive	94.1	94.2
Dead	5.9	5.8
Hospital, %		
Type[b]		
Large	73.9	30.4
Medium	23.5	56.5
Small	2.6	13.1
Ownership status[b]		
Public	4.3	2.9
Not for profit	49.4	0.0
Private	46.3	97.1
PCI-capable hospital with continuous coverage	86.5	0.0[b]
Level of trauma system by hospital[b]		
1	3.3	0.0
2	14.7	0.0
3	59.7	0.0
4	7.9	0.0
Undesignated	14.4	69.6

[a]*Arkansas residents from Miller, Lafayette, Little River, Sevier, Crittenden, and St Francis counties.*

[b]*$P < 0.05$.*

AMI, acute myocardial infarction; PCI, percutaneous coronary intervention; SD, standard deviation.

Multivariate Analysis

A mixed-effects logistic model assessed the effect of system factors (Table 4). AMI mortality was significantly associated with the distance to the nearest hospital (odds ratio [OR] 1.092, 95% confidence interval [CI] 1.009–1.181) and the number of hospitals per 1000 population in the county (OR 1.46, 95% CI 1.17–1.76) after adjusting for individual and environmental (contextual) factors. Results from the nested model that assessed hospital characteristics associated with AMI mortality (Table 5) showed a significant association with not having a PCI-capable hospital with continuous coverage (OR 1.64, 95% CI 1.15–2.34), after adjusting for individual and hospital characteristics.

Sensitivity Analysis

Although most of the results were consistent with the hypothesized direction of association, the finding that AMI mortality was associated with having a larger number of hospitals per 1000 population in the county was not expected. To further explore this association, a sensitivity analysis was conducted. Three counties (Desha, Dallas, and Arkansas) were identified with relatively larger numbers of hospitals per 1000 population in the county. When these three outlier counties were excluded, the number of hospitals per 1000 population variable was no longer significant in the multivariate model; however, the other variables remained significant.

Discussion

This study showed that deaths from AMI were significantly associated with system factors after adjusting for individual and environmental factors—a 9.2% increase in the odds of AMI death for every 10-mi increase in distance to the nearest hospital (OR 1.092, 95% CI 1.009–1.181) and a 64% increase in the odds of AMI death in hospitals without continuous PCI capability (OR 1.64, 95% CI 1.15–2.34). Individual factors such as age, being male, and being African American also were found to be significant predictors of AMI mortality. Although some of the study results are consistent with the current body of knowledge on factors associated with AMI mortality,[2–5,18–22] to our knowledge, this is the first study to evaluate the association between system factors and AMI mortality after adjusting for individual and environmental/contextual factors. The present study findings may have significant implications for public health practice, policy, and research.

Timely access to care following an AMI is critical. A coordinated system in which communities, EMS, and hospitals have a predetermined plan for transportation and care for individuals with AMI fosters timely access to care and averts deaths from AMI.[23] Distance to the hospital and the hospital's lack of continuous PCI capability pose barriers to developing a coordinated system of care.

The present study found that the average distance to the nearest hospital among individuals who had an AMI was 6.6 mi in Arkansas. Few studies have assessed the distance to the nearest hospital among individuals who had an AMI. For example, a study by Kansagra and colleagues on 97,401 patients from New York, New Jersey, and Florida found that the average distance to the nearest hospital was 5.7 mi.[24] Similarly, a study conducted in Los Angeles County to assess the distance to the nearest hospital found the average distance to be 2.65 mi.[12] Both of those studies, however, characterized distance to care in urban settings compared with the present study, which is set in a rural and medically underserved state. A study conducted in Sweden found that the probability of surviving an AMI declined 2 percentage points for every additional 10 km of distance from a hospital.[13] Our study found a 9.2% increase in the odds of AMI death for every 10-mi increase in distance to the nearest hospital

Table 4. Results from mixed-model regression analysis of system factors to AMI mortality in Arkansas

Variable	Estimate	SE	*t*	*P*	OR	95% CI	
						Lower limit	Upper limit
Distance to nearest hospital, mi	0.0088	0.0040	2.19	0.0285	1.0088[a]	1.0009	1.0168
No. EMS agencies/1000 population in county	0.6960	0.9576	0.73	0.4674	2.0057	0.3069	13.1051
No. hospitals/1000 population in county	0.3616	1.8215	1.99	0.0472	1.4356[a]	1.0046	2.0516
No. continuous PCI-capable hospitals/1000 population in county	−14.3399	8.7536	−1.64	0.1014	0.0000	0.0000	16.7484
Age	0.0277	0.0014	19.8	<0.0001	1.0281[a]	1.0253	1.0309
Male	0.1857	0.0400	−4.64	<0.0001	1.2041[a]	1.1132	1.3023
African American	0.3278	0.0710	4.61	<0.0001	1.3879[a]	1.2074	1.5952
Living in poverty	0.0254	0.0134	1.89	0.0587	1.0257	0.9991	1.0530
Uninsured	0.0157	0.0277	0.57	0.5712	1.0158	0.9621	1.0725
Obesity	0.0047	0.0146	0.33	0.7452	1.0047	0.9765	1.0339
Current smoker	−0.0003	0.0178	−0.02	0.9876	0.9997	0.9654	1.0353
Coronary heart disease	−0.0659	0.0460	−1.43	0.152	0.9363	0.8556	1.0245
Diabetes mellitus	0.0298	0.0273	1.09	0.274	1.0303	0.9767	1.0868
Hypertension	0.0284	0.0160	1.77	0.077	1.0288	0.9969	1.0616
High cholesterol	−0.0206	0.0142	−1.45	0.1465	0.9796	0.9528	1.0072
Depression	0.0256	0.0202	1.27	0.2047	1.0259	0.9861	1.0673
Awareness of AMI signs and symptoms	−0.0359	0.0220	−1.63	0.1031	0.9648	0.9240	1.0073
Intent to call 9-1-1 for AMI	−0.0209	0.0179	−1.17	0.2425	0.9793	0.9456	1.0143

AMI, acute myocardial infarction; CI, confidence interval; OR, odds ratio; PCI, percutaneous coronary intervention; SE, standard error.
[a]*$P < 0.05$.*

(or 5.8 percentage points for every additional 10 km of distance from a hospital). The National Heart Attack Alert Program recommends that individuals who have symptoms and signs of an AMI call 9-1-1 for transport to the appropriate hospital via an EMS rather than driving themselves, or having their next of kin or neighbor drive them to the hospital.[14–16] Although distance to the nearest hospital is an important factor associated with AMI mortality, the drive time to cover the distance to the hospital through EMS is critical for a time-sensitive condition such as AMI.[20,21]

Table 5. Results from mixed-model regression analysis of hospital characteristics to AMI mortality in Arkansas

Variable	Estimate	SE	*t*	*P*	OR	95% CI	
						Lower limit	Upper limit
Hospital size							
Large vs small	0.1596	0.253	0.63	0.5281	1.17	0.71	1.93
Medium vs small	0.0367	0.2454	0.15	0.8811	1.04	0.64	1.68
Public vs privately owned hospital	0.2533	0.3087	0.82	0.4119	1.29	0.70	2.36
Not for profit vs privately owned hospital	0.2379	0.136	1.75	0.0803	1.27	0.97	1.66
Lack of continuous PCI capability	0.496	0.1799	2.76	0.0058	1.64*	1.15	2.34
Trauma level							
0 vs 4	0.0549	0.2231	0.25	0.8053	1.06	0.68	1.64
1 vs 4	−0.0864	0.4743	−0.18	0.8555	0.92	0.36	2.32
2 vs 4	−0.1608	0.2421	−0.66	0.5067	0.85	0.53	1.37
3 vs 4	−0.0281	0.1809	−0.16	0.8767	0.97	0.68	1.39
Age	0.0493	0.0033	14.82	<0.0001	1.05*	1.04	1.06
Male sex	0.1653	0.0854	−1.93	0.0532	1.18	0.72	1.00
African American	0.2181	0.1508	1.45	0.1481	1.24	0.93	1.67

AMI, acute myocardial infarction; CI, confidence interval; OR, odds ratio; PCI, percutaneous coronary intervention; SE, standard error.
[a]*$P < 0.05$.*

The present study also found that the odds of death from AMI are 1.64 times higher among individuals who were discharged from a hospital without PCI capability compared with those with continuous PCI coverage. To our knowledge, the present study is the first to report this association in a rural state. A previous study by Graves that evaluated the association between PCI-capable hospitals and county age-adjusted MI mortality rates in the rural states of Alabama and Mississippi did not find this association.[22] A review of new PCI programs in US hospitals for the period 2004–2008 showed that the PCI programs were introduced in areas that already had a PCI program, leading to a systematic duplication of resources.[25] The review further concluded that the new PCI programs were introduced in areas with more competition for the market share, near populations with higher rates of private insurance, in states with weak or no regulation of new cardiac catheterization laboratories, and in wealthier and larger hospitals. It is estimated that the cost of introducing a new PCI program could range between $7.8 and $16.4 million, depending on the availability of backup surgical support services.[26] Establishing these services can be a costly enterprise, and given that it is estimated that a hospital needs at least 200 patients with AMI annually to justify the expense,[26] the volume of patients who need a PCI program may not be sufficient in rural areas. For this reason, several communities across the United States have developed regional hospital networks between PCI and non-PCI hospitals to foster coordination in their system of care.[22] Part of the networks includes initiating public health efforts to foster community education about the signs and symptoms of AMI, calling 9-1-1, and using EMS for transportation to an appropriate hospital for AMI care, and developing a regional system of care through collaboration and coordination between EMS and hospitals (PCI and non-PCI) on clinical pathways.

Our study has a few potential limitations. Data on several of the individual risk factors and comorbid conditions for AMI were not available at the individual level. Environmental (contextual) data at the county level was used in the analysis. The substitution of county-level data for individual-level data is not ideal and limits the precision of the results. The data on Arkansas residents who died in Arkansas or were discharged from an Arkansas hospital were complete; however, information on Arkansas residents who live in counties bordering other states and were treated and discharged from a hospital in a neighboring state was not complete. Although the determination of underlying cause of death is completed by a trained nosologist following specific guidelines distributed by the National Center for Health Statistics, the sensitivity of coding may be affected by the coroner or the healthcare provider who pronounced the death.[27] The exclusion of these cases results in an underrepresentation of individuals living in border counties, as reflected in the characteristics of the excluded sample in Tables 2 and 3. A potential source of misclassification is that the county of residence was used as a proxy for the location of the event. Although presence of a licensed EMS agency in a county was assessed, EMS coverage was not assessed because many EMS agencies provide services to neighboring counties. Lastly, using deaths from AMI and discharges after AMI treatment as independent events has merit; however, such events may not be truly independent because an individual may have multiple AMIs, with each event influencing the possibility of a subsequent event.

Conclusions

Healthcare system factors may play a significant role in death from AMI, especially distance to the nearest hospital and hospitals' continuous PCI capability, even after adjusting for individual and environmental factors. A coordinated system of care approach that mitigates gaps in system factors could prevent death from AMI.

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