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Case Rates, Treatment Approaches, and Outcomes in Acute Myocardial Infarction During the Coronavirus Disease 2019 Pandemic

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IMPORTANCE The coronavirus disease 2019 (COVID-19) pandemic has changed health care delivery worldwide. Although decreases in hospitalization for acute myocardial infarction (AMI) have been reported during the pandemic, the implication for in-hospital outcomes is not well understood.

OBJECTIVE To define changes in AMI case rates, patient demographics, cardiovascular comorbidities, treatment approaches, and in-hospital outcomes during the pandemic.

DESIGN, SETTING, AND PARTICIPANTS This cross-sectional study retrospectively analyzed AMI hospitalizations that occurred between December 30, 2018, and May 16, 2020, in 1 of the 49 hospitals in the Providence St Joseph Health system located in 6 states (Alaska, Washington, Montana, Oregon, California, and Texas). The cohort included patients aged 18 years or older who had a principal discharge diagnosis of AMI (ST-segment elevation myocardial infarction [STEMI] or non–ST-segment elevation myocardial infarction [NSTEMI]). Segmented regression analysis was performed to assess changes in weekly case volumes. Cases were grouped into 1 of 3 periods: before COVID-19 (December 30, 2018, to February 22, 2020), early COVID-19 (February 23, 2020, to March 28, 2020), and later COVID-19 (March 29, 2020, to May 16, 2020). In-hospital mortality was risk-adjusted using an observed to expected (O/E) ratio and covariate-adjusted multivariable model.

EXPOSURE Date of hospitalization.

MAIN OUTCOMES AND MEASURES The primary outcome was the weekly rate of AMI (STEMI or NSTEMI) hospitalizations. The secondary outcomes were patient characteristics, treatment approaches, and in-hospital outcomes of this patient population.

RESULTS The cohort included 15 244 AMI hospitalizations (of which 4955 were for STEMI [33%] and 10 289 for NSTEMI [67%]) involving 14 724 patients (mean [SD] age of 68 [13] years and 10 019 men [66%]). Beginning February 23, 2020, AMI-associated hospitalizations decreased at a rate of −19.0 (95% CI, −29.0 to −9.0) cases per week for 5 weeks (early COVID-19 period). Thereafter, AMI-associated hospitalizations increased at a rate of +10.5 (95% CI, +4.6 to +16.5) cases per week (later COVID-19 period). No appreciable differences in patient demographics, cardiovascular comorbidities, and treatment approaches were observed across periods. The O/E mortality ratio for AMI increased during the early period (1.27; 95% CI, 1.07-1.48), which was disproportionately associated with patients with STEMI (1.96; 95% CI, 1.22-2.70). Although the O/E mortality ratio for AMI was not statistically different during the later period (1.23; 95% CI, 0.98-1.47), increases in the O/E mortality ratio were noted for patients with STEMI (2.40; 95% CI, 1.65-3.16) and after risk adjustment (odds ratio, 1.52; 95% CI, 1.02-2.26).

CONCLUSIONS AND RELEVANCE This cross-sectional study found important changes in AMI hospitalization rates and worse outcomes during the early and later COVID-19 periods. Future studies are needed to identify contributors to the increased mortality rate among patients with STEMI.

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Supplemental content

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The coronavirus disease 2019 (COVID-19) pandemic has profoundly changed health care delivery worldwide. Although early attention to COVID-19 was disproportionately focused on efforts to flatten the (pandemic) curve, recent studies have revealed a substantial decrease in hospitalization rates for acute myocardial infarction (AMI). Reports from Austria,[1] Italy,[2] and the US (California)[3] have noted lower admission rates for both ST-segment elevation myocardial infarction (STEMI) and non-ST-segment elevation myocardial infarction (NSTEMI). This decreased hospitalization rate likely reflects multiple factors. Most worrisome among these factors has been the reluctance of patients with AMI to seek medical attention out of fear that they may become infected with severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2).[4]

We performed a retrospective, cross-sectional study of all AMI hospitalizations in a large multistate health care system. We sought to define changes in AMI case rates, patient demographics, cardiovascular comorbidities, treatment approaches, and in-hospital outcomes during the pandemic.

Key Points

Question How have case rates, treatment approaches, and in-hospital outcomes changed for patients with acute myocardial infarction (AMI) during the coronavirus disease 2019 (COVID-19) pandemic?

Findings In this cross-sectional study of 15 244 hospitalizations involving 14 724 patients with AMI, case rates began to decrease on February 23, 2020, followed by a modest recovery after 5 weeks. Although no statistically significant difference in treatment approaches was found, the risk-adjusted mortality rate among patients with ST-segment elevation myocardial infarction increased substantially.

Meaning The findings of this study show that changes in AMI hospitalizations and in-hospital outcomes occurred during the COVID-19 pandemic periods analyzed; additional research is warranted to explain the higher mortality rate among patients with ST-segment elevation myocardial infarction.

Methods

This study included patients aged 18 years or older with a principal discharge diagnosis of AMI who were admitted between December 30, 2018, and May 16, 2020, into 1 of 49 hospitals in the Providence St Joseph Health (PSJH) system located in 6 states (Alaska, Washington, Montana, Oregon, California, and Texas). We used *International Statistical Classification of Diseases and Related Health Problems, Tenth Revision*, codes to define the population (eTable 1 in the Supplement). Individuals who were admitted as an outpatient were excluded. This study was approved by the PSJH Institutional Review Board, which waived the informed consent requirement because of the retrospective nature of the study.

The primary outcome was the weekly rate of AMI (STEMI or NSTEMI) hospitalizations before and after the pandemic onset. The secondary outcomes were patient characteristics, treatment approaches, and in-hospital outcomes (mortality, length of stay, and discharge disposition) of patients with STEMI or NSTEMI. Treatment approaches were defined by Medicare Severity-Diagnosis Related Groups (MS-DRGs) for percutaneous coronary intervention, coronary artery bypass graft surgery, and medical management of AMI (eTable 2 in the Supplement).

Time Series Analyses for Changes in Case Rates

Weekly volumes of AMI hospitalizations (categorized as STEMI or NSTEMI) are presented in the **Figure** as line graphs. Segmented regression analysis was used to ascertain volume changes over time. Using 2 identified break points (February 23, 2020 and March 29, 2020), we grouped cases into 1 of 3 periods for analysis: before COVID-19 (December 30, 2018, to February 22, 2020), early COVID-19 (February 23, 2020, to March 28, 2020), and later COVID-19 (March 29, 2020, to May 16, 2020). Segmented regression analysis was also used to identify the slope change in weekly hospitalizations during the 3 periods, with consideration of time dependence in the model.

Risk-Adjusted Mortality

Risk-adjusted in-hospital mortality was examined with 2 models. The first was the PSJH mortality risk model, which was a lookup table consisting of more than 5430 expected mortality rates. Such data were derived from the 3M All Patient Refined DRG, risk of mortality, and severity-of-illness grouper algorithm applied to a large inpatient database in the western US (eMethods in the Supplement). The second was a multivariable logistic model, which considered all demographic variables listed in **Table 1**. Results of the multivariable model were presented as adjusted odds ratio (OR) with 95% CI.

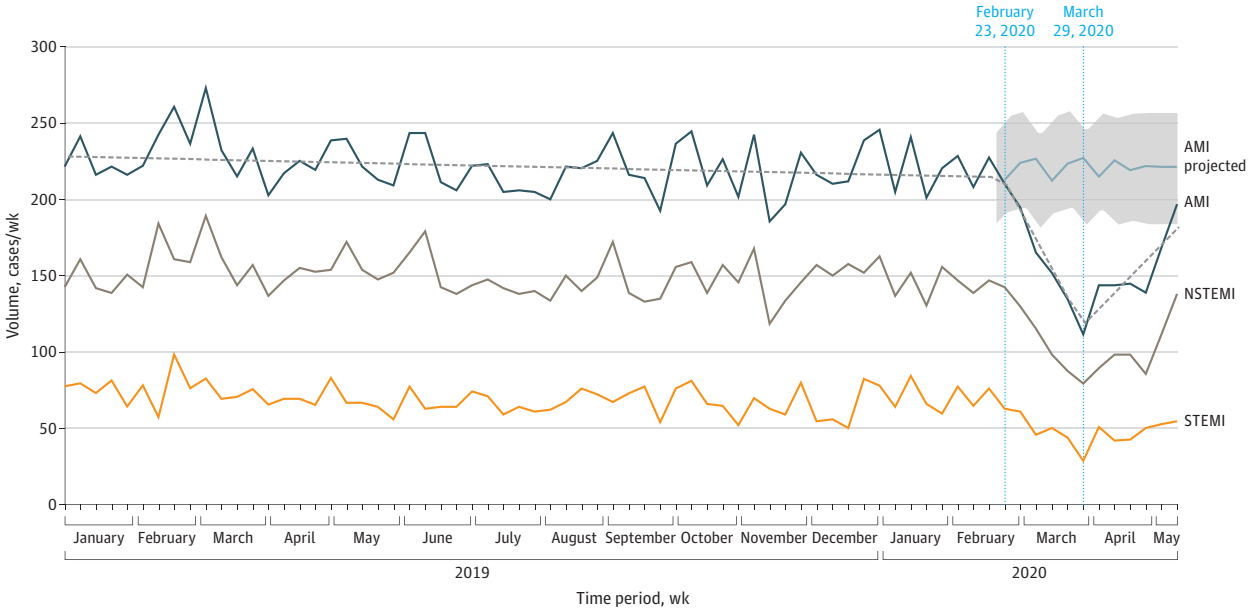
Statistical Analysis

Patient demographics, cardiovascular comorbidities, treatment approaches, and in-hospital outcomes were summarized as descriptive statistics. Categorical data were presented as frequency (percentage). Numeric data were tested for normality and presented as mean (SD) or median (interquartile range [IQR]), as appropriate. Trends among the 3 COVID-19 periods were compared using univariate χ^2, Fisher exact, or Kruskal-Wallis tests, as appropriate, for each variable. The level of statistical significance varied from $P < .05$ to $P < .008$, depending on Bonferroni adjustment for multiple comparisons (eMethods in the Supplement).

Results

The study cohort comprised 15 244 hospitalizations for AMI (4955 for STEMI [33%] and 10 289 for NSTEMI [67%]) involving 14 724 patients. Of those hospitalized, 5225 were women (34%) and 10 019 were men (66%), with a mean (SD) age of 68 (13) years (Table 1). Before the COVID-19 period, the mean (SD) weekly case rate was 222 (17) patients for AMI, 72 (9) patients for STEMI, and 150 (13) patients for NSTEMI (Figure and eTable 3 in the Supplement). Beginning February 23, 2020, AMI

Figure. Weekly Case Rates of Acute Myocardial Infarction (AMI), Non-ST-Segment Elevation Myocardial Infarction (NSTEMI), and STEMI Over Time



The start of the early coronavirus disease 2019 (COVID-19) period (February 23, 2020) and later COVID-19 period (March 29, 2020), as defined by segmented regression analysis, are indicated by vertical lines. Dotted lines indicate the best-fit regression lines for the 3 periods (including the before COVID-19 period). Projected volumes with 95% CIs are displayed in gray. STEMI indicates ST-segment elevation myocardial infarction.

hospitalizations decreased at a rate of -19.0 (95% CI, -29.0 to -9.0) cases per week for 5 weeks, marking the early COVID-19 period (Figure). Thereafter, AMI hospitalizations increased at a rate of +10.5 (95% CI, +4.6 to +16.5) cases per week, marking the later COVID-19 period. Weekly AMI hospitalization rates had not returned to baseline, however, by the last week evaluated (May 10, 2020; eTable 3 in the Supplement). Similar trends in hospitalization for AMI, STEMI, and NSTEMI were observed in the PSJH system in all 6 states (eFigure 1 in the Supplement).

Patients hospitalized for AMI in the early and later COVID-19 periods vs the before period were slightly younger (mean [SD] age, 67 [13] years vs 68 [13] years; $P < .001$) and more likely to be Asian (50 [6%] and 62 [6%] vs 667 [5%]; $P = .01$) or Native American individuals (20 [2%] and 21 [2%] vs 151 [1%]; $P = .01$) (Table 1). Treatment approaches for patients with STEMI or NSTEMI were not statistically different across periods (eFigure 2 in the Supplement). Median (IQR) length of stay for patients with AMI was shorter in the early COVID-19 period by 7 hours and in the later COVID-19 period by 6 hours compared with the before period (56 [41-115] hours and 57 [41-116] hours vs 63 [43-122] hours, respectively; $P < .001$) (**Table 2**). Similar trends were observed for both types of AMI. A greater number of patients with AMI were discharged to home in the early and later COVID-19 periods vs the before COVID-19 period, with consistent findings among those with STEMI (235 [83%] and 284 [81%] vs 3402 [79%]; $P = .02$) and NSTEMI (465 [81%] and 587 [83%] vs 6976 [77%]; $P = .006$).

The observed (crude) in-hospital mortality rate was similar between periods for all groups (Table 2). Compared with the before COVID-19 period, however, patients with STEMI had a statistically greater risk of mortality during the later COVID-19 period after adjusting for patient demographic characteristics and comorbidities (OR, 1.52; 95% CI, 1.02-2.26). Using the PSJH model, the observed to expected (O/E) hospital mortality ratio for patients with AMI was statistically increased in the early COVID-19 period (O/E ratio, 1.27; 95% CI, 1.07-1.48), with consistent findings in the later period as well (O/E ratio, 1.23; 95% CI, 0.98-1.47). These findings, however, were different for patients with STEMI vs those with NSTEMI. For patients with STEMI, the O/E mortality ratio was substantially higher in all 3 COVID-19 periods. These patients had a stepwise increase in the O/E mortality ratio from the before period (O/E ratio, 1.48; 95% CI, 1.34-1.62) to the early (O/E ratio, 1.96; 95% CI, 1.22-2.70) and later (O/E ratio, 2.40; 95% CI, 1.65-3.16) periods. The O/E mortality ratio for STEMI in the later period was statistically greater than the before period. In contrast, patients with NSTEMI had a consistently lower O/E mortality ratio for all 3 periods (before: O/E ratio, 0.80 [95% CI, 0.71-0.88]; early: O/E ratio, 0.91 [95% CI, 0.46-1.36]; later: O/E ratio, 0.71 [95% CI, 0.49-0.93]).

Discussion

Consistent with previous reports, this study found a substantial decrease in AMI hospitalization rates in the early COVID-19 period. Beginning March 29, 2020, however, hospitalizations for AMI began to increase, albeit at a slower rate. Among the many factors likely associated with this rebound in cases was encouragement of patients with symptoms or signs of AMI to seek immediate medical attention, even amid the pandemic.[5,6]

Table 1. Patient Demographics

Variable	No. (%)[a]											
	All AMI				STEMI				NSTEMI			
	COVID-19 period				COVID-19 period				COVID-19 period			
	Before	Early	Later	*P* value	Before	Early	Later	*P* value	Before	Early	Later	*P* value
No. (%)	13 329 (87)	860 (6)	1055 (7)	NA	4320 (87)	284 (6)	351 (7)	NA	9009 (88)	576 (6)	704 (7)	NA
Demographics												
Age, mean (SD), y	68 (13)	67 (13)	67 (13)	<.001	66 (13)	64 (12)	63 (13)	.001	70 (13)	69 (13)	68 (13)	.004
Female sex	4592 (34)	276 (32)	357 (34)	.35	1207 (28)	73 (26)	88 (25)	.39	3385 (38)	203 (35)	269 (38)	.49
Race												
White	10 374 (80)	663 (79)	796 (78)	.01	3310 (79)	208 (76)	264 (80)	.02	7064 (80)	455 (80)	532 (77)	.30
Asian	667 (5)	50 (6)	62 (6)		232 (6)	17 (6)	24 (7)		435 (5)	33 (6)	38 (6)	
Black	458 (4)	23 (3)	38 (4)		111 (3)	3 (1)	4 (1)		347 (4)	20 (4)	34 (5)	
Native American	151 (1)	20 (2)	21 (2)		52 (1)	10 (4)	8 (2)		99 (1)	10 (2)	13 (2)	
Pacific Islander	99 (1)	3 (0)	4 (0)		23 (1)	1 (0)	1 (0)		76 (1)	2 (0)	3 (0)	
Other	1287 (10)	85 (10)	96 (9)		456 (11)	36 (13)	29 (9)		831 (9)	49 (9)	67 (10)	
Ethnicity												
Hispanic	1568 (12)	98 (12)	105 (10)	.26	520 (13)	36 (13)	30 (9)	.18	1048 (12)	62 (11)	75 (11)	.64
Non-Hispanic	11 410 (88)	738 (88)	909 (90)		3640 (88)	236 (87)	298 (91)		7770 (88)	502 (89)	611 (89)	
Comorbidities[b]												
Hypertension	10 983 (82)	704 (82)	869 (82)	.92	3224 (75)	215 (76)	260 (74)	.89	7759 (86)	489 (85)	609 (87)	.67
Hypercholesterolemia	9935 (75)	644 (75)	810 (77)	.27	3061 (71)	213 (75)	262 (75)	.12	6874 (76)	431 (75)	548 (78)	.45
Diabetes	1456 (11)	106 (12)	119 (11)	.43	507 (12)	44 (15)	42 (12)	.17	949 (11)	62 (11)	77 (11)	.93
Current smoker	3078 (32)	199 (32)	268 (35)	.31	942 (30)	66 (31)	95 (35)	.28	2136 (33)	133 (32)	173 (34)	.67
Prior MI	2763 (21)	171 (20)	224 (21)	.77	639 (15)	37 (13)	62 (18)	.23	2124 (24)	134 (23)	162 (23)	.93
Cerebrovascular disease	1116 (8)	64 (7)	74 (7)	.21	242 (6)	15 (5)	22 (6)	.85	874 (10)	49 (9)	52 (7)	.09
PAD	1449 (11)	90 (10)	130 (12)	.31	294 (7)	19 (7)	21 (6)	.84	1155 (13)	71 (12)	109 (15)	.11
Heart failure	5079 (38)	316 (37)	388 (37)	.53	1280 (30)	88 (31)	96 (27)	.57	3799 (42)	228 (40)	292 (41)	.46

Abbreviations: AMI, acute myocardial infarction; COVID-19, coronavirus disease 2019; MI, myocardial infarction; NA, not applicable; NSTEMI, non–ST-segment elevation myocardial infarction; PAD, peripheral artery disease; STEMI, ST-segment elevation myocardial infarction.

[a] Percentages may not add to 100 because of rounding.

[b] Comorbidities identified during the index hospitalization.

Table 2. In-Hospital Outcomes

Variable	All AMI				STEMI				NSTEMI			
	COVID-19 period				COVID-19 period				COVID-19 period			
	Before	Early	Later	*P* value	Before	Early	Later	*P* value	Before	Early	Later	*P* value
Mortality, OR (95% CI)												
Unadjusted	1 [Reference]	0.95 (0.69-1.31)	1.02 (0.77-1.35)	NA	1 [Reference]	1.03 (0.66-1.60)	1.26 (0.87-1.82)	NA	1 [Reference]	0.86 (0.54-1.38)	0.78 (0.50-1.22)	NA
Risk-adjusted	1 [Reference]	1.02 (0.74-1.42)	1.14 (0.86-1.53)	NA	1 [Reference]	1.18 (0.74-1.87)	1.52 (1.02-2.26)	NA	1 [Reference]	0.91 (0.56-1.47)	0.85 (0.54-1.34)	NA
O/E ratio, mean (95% CI)[a]	1.04 (0.96-1.11)	1.27 (1.07-1.48)	1.23 (0.98-1.47)	NA	1.48 (1.34-1.62)	1.96 (1.22-2.70)	2.40 (1.65-3.16)	NA	0.80 (0.71-0.88)	0.91 (0.46-1.36)	0.71 (0.49-0.93)	NA
LOS, median (IQR), h	63 (43-122)	56 (41-115)	57 (41-116)	<.001	55 (42-96)	53 (43-100)	51 (41-83)	.15	68 (44-139)	60 (39-118)	63 (42-125)	<.001
Medical management	64 (41-107)	57 (33-97)	55 (38-98)	.005	57 (29-98)	47 (39-97)	54 (29-89)	.86	65 (42-108)	58 (33-97)	55 (38-100)	.003
PCI	51 (41-77)	49 (38-68)	50 (41-74)	.001	51 (42-72)	50 (42-68)	49 (41-69)	.15	52 (41-85)	47 (35-69)	51 (41-83)	.002
CABG	215 (171-282)	204 (155-275)	211 (170-263)	.36	209 (166-263)	192 (159-336)	212 (129-276)	.86	215 (172-285)	208 (150-268)	211 (170-263)	.26
Discharge disposition, No. (%)[b]												
Home[c]	10 378 (78)	700 (81)	871 (83)	<.001	3402 (79)	235 (83)	284 (81)	.02	6976 (77)	465 (81)	587 (83)	.006
Transfer to other facility[d]	1922 (14)	94 (11)	104 (10)		508 (12)	23 (8)	26 (7)		1414 (16)	71 (12)	78 (11)	
Expired	683 (5)	42 (5)	55 (5)		340 (8)	23 (8)	34 (10)		343 (4)	19 (3)	21 (3)	
Hospice[e]	194 (2)	18 (2)	9 (1)		34 (1)	3 (1)	1 (0)		160 (2)	15 (3)	8 (1)	
Other	152 (1)	6 (1)	16 (2)		36 (1)	0	6 (2)		116 (1)	6 (1)	10 (1)	

Abbreviations: AMI, acute myocardial infarction; CABG, coronary artery bypass graft; COVID-19, coronavirus disease 2019; IQR, interquartile range; LOS, length of stay; MI, myocardial infarction; NA, not applicable; NSTEMI, non–ST-segment elevation myocardial infarction; O/E, observed to expected; OR, odds ratio; PCI, percutaneous coronary intervention; STEMI, ST-segment elevation myocardial infarction.

[a] Based on the Providence St Joseph Health all-cause inpatient mortality risk model.

[b] Percentages may not add to 100 because of rounding.

[c] With or without health care services.

[d] General or specialty hospital, skilled or intermediate care facility, swing bed, rehabilitation facility, or other institution.

[e] At home or medical facility.

Although patient demographics and treatment approaches were fairly consistent across periods, patients with AMI hospitalized during the COVID-19 period were 1 to 3 years younger, had a shorter length of stay, and were more likely to be discharged to home. Possible explanations for these findings were greater reluctance by older patients to seek medical attention, hospital efforts to maintain bed availability, patient preference for early discharge, and concern about risk of contracting SARS-CoV-2 in post-acute care facilities.

Notable differences in risk-adjusted mortality were observed over the periods analyzed. Patients hospitalized for AMI during the early COVID-19 period had an increased O/E mortality ratio, associated disproportionately with patients with STEMI. In this population, the O/E ratio and risk-adjusted mortality rates were even greater during the later COVID-19 period. Given the time-sensitive nature of STEMI, any delay by patients, emergency medical services, the emergency department, or cardiac catheterization laboratory may have played a role.[7,8] Additional complications from delayed reperfusion (eg, conduction disturbances, heart failure, cardiogenic shock, and mechanical complications)[9] may have occurred in some patients. Further research is needed to identify factors associated with the higher mortality rate in patients with STEMI.

In the weeks and months to come, clinicians may see greater numbers of patients with more severe manifestations of AMI. With the uncertainty on timing of a COVID-19 vaccine, this study reinforces the need to address important care processes for patients with AMI to help mitigate further risk.

Limitations

This study has several limitations. First, because the cohort was defined by coding data, it is possible that the primary reason for hospitalization was misclassified as an AMI. Second, the treatment analysis excluded outpatients and those with other MS-DRG codes. Although this group represented a small percentage of the total patient cohort (8% [1165]), treatment shifts may have been underappreciated. Third, the data set did not allow us to evaluate potential timing-related factors that may have contributed to higher in-hospital mortality (eg, time of symptom onset, first medical contact, and hospital arrival). Fourth, although the PSJH mortality risk model is not AMI-specific, we found consistent results with a multivariable model adjusted for patient demographic characteristics and comorbidities. Fifth, the COVID-19 status of patients included in the analysis was not available. As such, the higher observed rate of AMI mortality during the COVID-19 period could have been associated with concurrent SARS-CoV-2 infection.

Conclusions

Results of this cross-sectional study appear to validate previous concerns that large numbers of patients with AMI initially avoided hospitalization during the COVID-19 pandemic, likely out of fear of contracting SARS-CoV-2. Hospitalization rates for AMI have begun to increase but so has the risk of in-hospital mortality. Further research into factors associated with an increase in the STEMI mortality rate is warranted.

ARTICLE INFORMATION

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Concept and design: Gluckman, Chiu, Penny, Spinelli.
Acquisition, analysis, or interpretation of data: All authors.
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