

ORIGINAL RESEARCH

Associations Between Hospital Length of Stay, 30-Day Readmission, and Costs in ST-Segment–Elevation Myocardial Infarction After Primary Percutaneous Coronary Intervention: A Nationwide Readmissions Database Analysis

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BACKGROUND: Readmission after ST-segment–elevation myocardial infarction (STEMI) poses an enormous economic burden to the US healthcare system. There are limited data on the association between length of hospital stay (LOS), readmission rate, and overall costs in patients who underwent primary percutaneous coronary intervention for STEMI.

METHODS AND RESULTS: All STEMI hospitalizations were selected in the Nationwide Readmissions Database from 2010 to 2014. From the patients who underwent primary percutaneous coronary intervention, we examined the 30-day outcomes including readmission, mortality, reinfarction, repeat revascularization, and hospital charges/costs according to LOS (1–2, 3, 4, 5, and >5 days) stratified by infarct locations. The 30-day readmission rate after percutaneous coronary intervention for STEMI was 12.0% in the anterior wall (AW) STEMI group and 9.9% in the non-AW STEMI group. Patients with a very short LOS (1–2 days) were readmitted less frequently than those with a longer LOS regardless of infarct locations. However, patients with a very short LOS had significantly increased 30-day readmission mortality versus an LOS of 3 days (hazard ratio, 1.91; CI, 1.16–3.16 [$P=0.01$]) only in the AW STEMI group. Total costs (index admission+readmission) were the lowest in the very short LOS cohort in both the AW STEMI group ($P<0.001$) and the non-AW STEMI group ($P<0.001$).

CONCLUSIONS: For patients who underwent primary percutaneous coronary intervention for STEMI, a very short LOS was associated with significantly lower 30-day readmission and lower cumulative cost. However, a very short LOS was associated with higher 30-day mortality compared with at least a 3-day stay in the AW STEMI cohort.

Key Words: costs ■ length of hospital stay ■ PCI ■ readmission ■ STEMI

See Editorial by Garratt

Recent advances in the treatment of ST-segment–elevation myocardial infarction (STEMI) have resulted in improved outcomes.^{1–3} However, STEMI remains a significant cause of morbidity and mortality

in the United States. It is estimated that nearly \$12.1 billion US dollars were spent in 2013 for hospital care of STEMI.^{4,5} Early discharge after primary percutaneous coronary intervention (PCI) for STEMI has been shown

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CLINICAL PERSPECTIVE

What Is New?

- In this large, nationwide cohort of patients hospitalized for ST-segment–elevation myocardial infarction (STEMI) undergoing primary percutaneous coronary intervention, we demonstrated that very early discharge strategy is associated with reduced readmissions and decreased overall cost in low-risk patients.
- Very short discharge (length of stay 1–2 days) after primary percutaneous coronary intervention for STEMI was associated with increased 30-day mortality compared with 3-daylength of stay in the anterior wall (AW) STEMI group but not in the non-AW STEMI group.
- Longer length of stay and readmissions were strong independent predictors of higher total costs in both patients with AW and those with non-AW STEMI.

What Are the Clinical Implications?

- Hospital length of stay appeared to be a marker of subsequent outcomes and total healthcare costs in patients hospitalized for STEMI undergoing primary percutaneous coronary intervention.
- Very early discharge after primary percutaneous coronary intervention for STEMI may represent potential strategies to decrease readmissions and to lower healthcare costs.
- Patients with AW STEMI need attention for very early discharge strategy considering potential increase in 30-day mortality.

Nonstandard Abbreviations and Acronyms

AMA	against medical advice
AW	anterior wall
CABG	coronary artery bypass grafting
HCUP	Healthcare Cost and Utilization Project
HMO	health maintenance organization
HR	hazard ratio
HRRP	hospital readmission reduction program
IABP	intra-aortic balloon pump
ICD-9-CM	<i>International Classification of Diseases, Ninth Revision, Clinical Modification</i>
LOS	length of stay
MACE	major adverse cardiac events
NCDR	National Cardiovascular Data Registry
NRD	Nationwide Readmissions Database
PCI	percutaneous coronary intervention
PLVAD	percutaneous left ventricular assist device
SE	standard error
STEMI	ST-segment–elevation myocardial infarction

to be feasible in multiple studies.^{6–9} However, the impact of shortening hospital length of stay (LOS) on re-admission remains an important question, especially since readmission after STEMI is still an enormous economic burden to the US healthcare system.¹⁰

As an effort to reduce readmissions and to improve quality of care, which can lead to significant cost reduction, the Centers for Medicare & Medicaid Services implemented the Hospital Readmission Reduction Program (HRRP) in several key diseases including acute myocardial infarction.¹¹ Recent studies demonstrated that about 20% of patients are readmitted within 30 days of hospitalization after STEMI, and significant efforts have been spent on identifying factors associated with 30-day readmissions.^{12–14} Our group recently demonstrated that 30-day readmission after STEMI was associated with an ~50% increase in cumulative hospital costs.¹⁵ Considering the recent trend of declining hospital LOS after STEMI,¹⁶ the association between LOS, readmissions, and costs needs to be further defined. Using the Nationwide Readmissions Database (NRD), we aimed to investigate the impact of LOS on the 30-day readmission rates and hospital costs after PCI in patients with STEMI stratified by the location of infarct.

METHODS

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Data Source

Data were obtained from the Agency for Healthcare Research and Quality, which administers the Healthcare Cost and Utilization Project (HCUP). We used NRD from 2010 to 2014. The NRD is a large administrative database constructed using discharge data from the HCUP State Inpatient Databases, with verified patient linkage numbers used to track the patients across hospitals within a state during a given year.¹⁷ The NRD is designed to support national readmission analyses and is a publicly available national representative healthcare database. From 2010 to 2014, the NRD contained deidentified information for total 70 501 787 index hospitalizations from 1715 to 2048 hospitals in 18 to 22 states, representing a national estimate of 181 545 077 discharges. Each patient record in the NRD contains information on the patient's diagnoses and procedures performed during the hospitalization based on *International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM)* codes and Clinical Classification Software (CCS) codes that groups multiple *ICD-9-CM* codes for facilitated

statistical analyses. We identified our study population, comorbidities, causes of readmissions, in-hospital outcomes using a combination of *ICD-9-CM* codes, and Clinical Classification Software codes. Institutional review board approval and informed consent were not required for current study because all data collection was derived from a publicly open and deidentified administrative database.

Study Population and Variables

All hospitalizations for STEMI with subsequent underwent PCI during index hospitalization were selected by finding *ICD-9-CM* codes for initial STEMI (410.x1) and PCI (00.66, 36.01, 36.02, 36.05, 36.06, and 36.07) (total unweighted N=228 953; weighted N=539 517). Subendocardial infarction (410.7x) was excluded from the analysis. In addition, patients who died during the index hospitalization were excluded in this cohort. To evaluate the effect of LOS and eliminate outliers, we included patients with a LOS from 1 day up to 14 days. LOS was calculated by subtracting the admission date from the discharge date. The LOS was categorized as follows: short LOS (LOS 1–3 days), medium LOS (LOS 4–5 days), and long LOS (LOS >5 days). We also examined the very short LOS (LOS 1–2 days) cohort versus those with a longer LOS after subdividing patients into 5 LOS cohorts (LOS 1–2, 3, 4, 5, and >5).

Patients with a concomitant diagnosis of cardiogenic shock and cardiac arrest were identified using *ICM-9-CM* codes 785.51 and 427.5, respectively. Concurrent use of intra-aortic balloon pump and percutaneous left ventricular assist devices were identified with *ICD-9-CM* procedure codes 37.61 and 37.68, respectively. Since NRD prohibits linking patients across years, patients discharged from January through November were included in the study to allow for completeness of data on 30 days of follow-up after discharge. Furthermore, patients with missing data on LOS were excluded to properly capture interval until readmission. Patient- and hospital-level variables were included as baseline characteristics. NRD variables were used to identify age, sex, median household income quartiles, primary payer, hospital teaching status, location, and bed size. *ICD-9-CM* codes for selected concurrent clinical diagnoses and procedures are listed in Table S1.

Study Outcomes

The primary outcome of this study was 30-day readmission rate described by the HCUP. Time to readmission was defined as the number of days from discharge date of index admission to readmission date. The first readmission in 30 days was included, and transfer to another hospital was not counted

as a readmission. The secondary outcomes within 30 days included rates of all-cause mortality, reinfarction (*ICD-9-CM* codes of 410.x1 except 410.7x), repeat revascularization, and major adverse cardiac events (MACE), defined as a composite of mortality, reinfarction, and repeat revascularization. Furthermore, cumulative hospital charges and costs for index hospitalizations and readmissions were examined according to LOS.

Statistical Analyses

All statistical analyses were performed using SAS software version 9.4 (SAS Institute Inc) and R statistical software version 3.5.1 (www.R-project.org) with its package “survey.” Discharge weight and stratum provided by NRD were used for all analyses and thus all reported numbers are weighted national estimates.¹⁷ Domain analysis was used for accurate variance calculations for subgroup analyses.¹⁸ All analyses accounted for NRD sampling design by including hospital-year fixed effects based on hospital identification number.¹⁹ We compared baseline patient- and hospital-level characteristics with STEMI and PCI stratified by the occurrence of 30-day readmission, LOS, and location of the infarct. Categorical variables are presented as frequencies and analyzed by Rao-Scott chi-square test. Continuous variables are shown as mean or median and were tested by either Mann–Whitney–Wilcoxon test or survey-specific linear regression test. To evaluate the predictive value of LOS and other covariates for primary and secondary outcomes, survey-specific univariate and multivariable Cox proportional hazards models were applied. Variables with $P < 0.1$ were included as initial covariates. Final parsimonious models were created by manual removal of each covariate based on Akaike information criterion while ensuring each removal did not result in >10% change in the measure of association for the primary predictor variable. Adjusted risks are presented as hazard ratios (HRs) together with 95% CIs and P values. For the cost analysis, the estimated cost for each hospitalization was calculated by the validated method of using cost-to-charge ratio provided by HCUP.²⁰ NRD data was merged with cost-to-charge ratio files provided by HCUP and then multiplied by the charge for each hospitalization with the respective cost-to-charge ratio. Cumulative total cost was defined as the cost of readmission plus the cost of the index admission. Afterward, we examined the predictors of cumulative cost by performing survey-specific multivariable linear regression test and log-transforming costs to achieve a normal distribution. All tests were 2-sided with $P < 0.05$ considered statistically significant.

RESULTS

Baseline Characteristics by LOS

During the study period, 539 517 patients underwent primary PCI after STEMI at 3682 sites. Overall, 187 557 patients (34.8%) presented with anterior wall (AW) STEMI, while 351 960 patients (65.2%) presented with non-AW (NAW) STEMI. The mean age was 60.8 years (standard error, 0.1) in the AW STEMI group and 61.2 years (standard error, 0.1) in the NAW STEMI group. The distribution of LOS in the overall patients, AW STEMI group, and NAW STEMI group is shown in Figure 1. Patients with AW STEMI were more likely to stay longer in the hospital than those with NAW STEMI (LOS mean±standard error: 3.7±0.1 versus 3.3±0.1; $P<0.001$). The proportion of patients in each LOS cohort was 69.7% ($n=375\ 996$) for short LOS, 17.6% ($n=94\ 936$) for medium LOS, and 12.7% ($n=68\ 583$) for long LOS. Among those who presented with AW STEMI, the proportion of each LOS cohort was 62.6% ($n=117\ 332$) for short LOS, 21.4% ($n=40\ 232$) for medium LOS, and 16.0% ($n=29\ 993$) for long LOS. In the NAW STEMI group, the proportion was 73.5% ($n=258\ 663$) for short LOS, 15.5% ($n=54\ 706$) for medium LOS, and 11.0% ($n=38\ 591$) for long LOS.

Tables 1 and 2 compare the baseline patient- and hospital-level characteristics according to LOS groups stratified by 30-day readmission. Patients in the medium or long LOS cohort were older and more likely to be women and have hypertension, diabetes mellitus, previous myocardial infarction, previous coronary artery bypass graft surgery, family history of coronary artery disease, congestive heart failure, peripheral vascular disorders, chronic pulmonary disease, chronic kidney disease, liver disease, anemia, atrial fibrillation, coagulopathy, cerebrovascular disease, fluid and electrolyte disorders, obesity, and other neurological disorders compared with the short LOS cohort in both AW and NAW STEMI groups (Table S2). In addition, patients in the medium or long LOS cohort were more likely to have concomitant cardiogenic shock or cardiac arrest and require support from intraaortic balloon pump or percutaneous left ventricular assist device in both the AW and NAW STEMI groups.

Thirty-Day Readmission by LOS

Overall incidence of 30-day readmission was higher in patients with AW STEMI than those with NAW STEMI (12.3% versus 9.9%, $P<0.001$). The rates of 30-day readmission in patients with AW STEMI were 8.7% in the short LOS cohort, 14.9% in the medium LOS cohort, and 21.1% in the long LOS cohort ($P<0.001$). The rate of 30-day readmission in patients with NAW STEMI were 7.7% in the short LOS cohort, 13.4% in the medium LOS cohort, and 19.5% in the long LOS

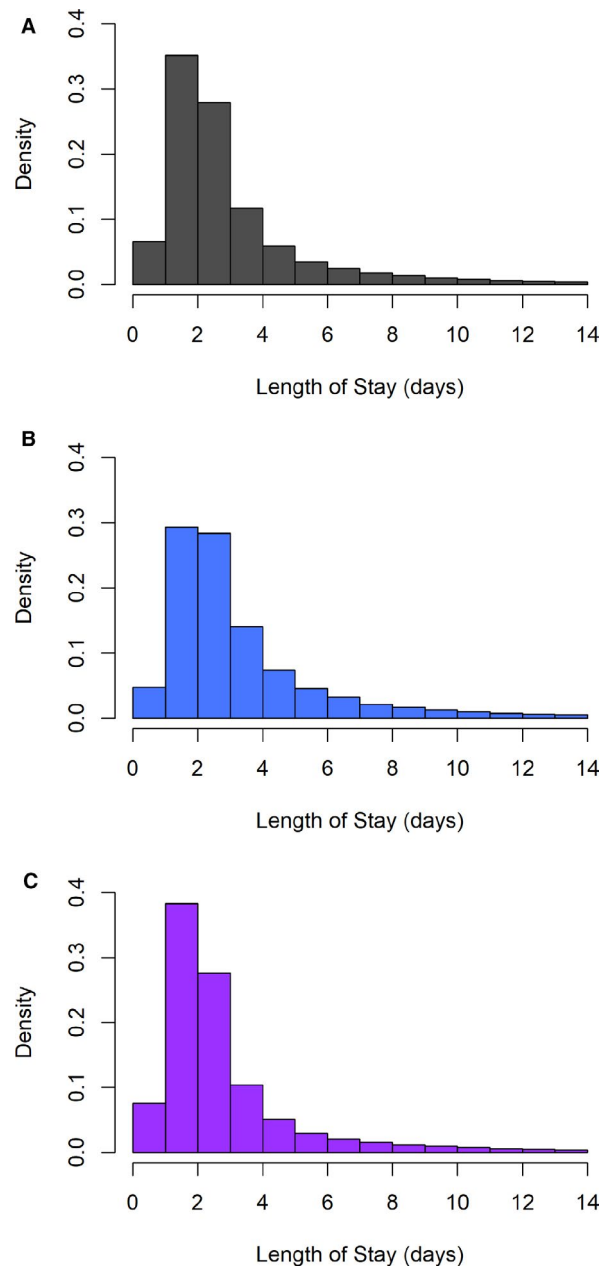


Figure 1. Histogram of length of hospital stay.

A, Density of length of stay (LOS) in overall patients. **B**, Density of LOS in patients with anterior wall (AW) myocardial infarction. **C**, Density of LOS in patients with non-AW myocardial infarction.

cohort ($P<0.001$). In the AW STEMI group, the 30-day readmission rates were 7.8% in the very short LOS (1–2 days) cohort, 9.8% in the 3-day LOS cohort, 13.8% in the 4-day LOS cohort, 16.9% in the 5-day LOS cohort, and 21.1% in the >5-day LOS cohort ($P<0.001$) (Figure 2A). In the NAW STEMI group, the 30-day readmission rates were 7.1% in the very short LOS cohort, 8.8% in the 3-day LOS cohort, 12.0% in

Table 1. Baseline Characteristics for Patients Discharged Alive After Index Hospitalization With STEMI in AW

Characteristics	Overall			LOS 1 to 3 d			30-d Readmission			LOS 4 to 5 d			LOS >5 d		
	No	Yes	P Value	No	Yes	P Value	No	Yes	P Value	No	Yes	P Value	No	Yes	P Value
Patients, No.	165 024 (88.0)*	22 533 (12.0)		107 122 (91.3)	10 210 (8.7)		34 251 (85.1)	5981 (14.9)		23 651 (78.9)	6342 (21.1)		23 651 (78.9)	6342 (21.1)	
Patient characteristics															
Age, mean (SE), y	60.3 (0.1)	64.3 (0.2)	<0.001†	59.0 (0.1)	62.2 (0.3)	<0.001†	61.7 (0.2)	64.9 (0.3)	<0.001†	64.3 (0.2)	67.6 (0.3)	<0.001†	64.3 (0.2)	67.6 (0.3)	<0.001†
Age group, y			<0.001†			<0.001†			<0.001			<0.001			<0.001
<50	33 283 (20.2)	3476 (15.4)		23 544 (22.0)	1841 (18.0)		6356 (18.6)	957 (16.0)		3383 (14.3)	679 (10.7)		3383 (14.3)	679 (10.7)	
50 to 64	73 823 (44.7)	7953 (35.3)		50 748 (47.4)	4023 (39.4)		14 263 (41.6)	2021 (33.8)		8812 (37.3)	1909 (30.1)		8812 (37.3)	1909 (30.1)	
≥65	57 918 (35.1)	11 103 (49.3)		32 831 (30.6)	4346 (42.6)		13 631 (39.8)	3004 (50.2)		11 456 (48.4)	3754 (59.2)		11 456 (48.4)	3754 (59.2)	
Women	41 087 (24.9)	7941 (35.2)	<0.001	23 239 (21.7)	3108 (30.4)	<0.001	9975 (29.1)	2273 (38.0)	<0.001	7874 (33.3)	2561 (40.4)	<0.001	7874 (33.3)	2561 (40.4)	<0.001
Smoking history	77 606 (47.0)	10 090 (44.8)	<0.001	52 876 (49.4)	4944 (48.4)	0.320	15 444 (45.1)	2685 (44.9)	0.877	9286 (39.3)	2461 (38.8)	0.709	9286 (39.3)	2461 (38.8)	0.709
Hypertension	100 897 (61.1)	15 186 (67.4)	<0.001	64 681 (60.4)	6702 (65.6)	<0.001	21 256 (62.1)	4123 (68.9)	<0.001	14 960 (63.3)	4361 (68.8)	<0.001	14 960 (63.3)	4361 (68.8)	<0.001
Diabetes mellitus	38 147 (23.1)	6367 (28.3)	<0.001	23 266 (21.7)	2692 (26.4)	<0.001	8700 (25.4)	1725 (28.8)	0.003	6182 (26.1)	1950 (30.8)	<0.001	6182 (26.1)	1950 (30.8)	<0.001
Dyslipidemia	94 442 (57.2)	12 791 (56.8)	0.494	62 864 (58.7)	5985 (58.6)	0.945	19 381 (56.6)	3388 (56.6)	0.961	12 197 (51.6)	3418 (53.9)	0.058	12 197 (51.6)	3418 (53.9)	0.058
Known coronary artery disease	144 171 (87.4)	19 748 (87.6)	0.531	93 590 (87.4)	8951 (87.7)	0.623	30 057 (87.8)	5279 (88.3)	0.525	20 525 (86.8)	5518 (87.0)	0.809	20 525 (86.8)	5518 (87.0)	0.809
Previous myocardial infarction	10 962 (6.6)	1844 (8.2)	<0.001	7123 (6.6)	802 (7.9)	0.011	2141 (6.3)	497 (8.3)	<0.001	1698 (7.2)	544 (8.6)	0.030	1698 (7.2)	544 (8.6)	0.030
Previous PCI	17 522 (10.6)	2744 (12.2)	<0.001	11 277 (10.5)	1212 (11.9)	0.018	3515 (10.3)	760 (12.7)	0.002	2731 (11.5)	773 (12.2)	0.414	2731 (11.5)	773 (12.2)	0.414
Previous CABG	1664 (1.0)	384 (1.7)	<0.001	969 (0.9)	157 (1.5)	<0.001	349 (1.0)	104 (1.7)	0.005	346 (1.5)	123 (1.9)	0.149	346 (1.5)	123 (1.9)	0.149
Family history of coronary artery disease	22 363 (13.6)	2421 (10.7)	<0.001	15 896 (14.8)	1288 (12.6)	<0.001	4310 (12.6)	670 (11.2)	0.126	2158 (9.1)	464 (7.3)	0.017	2158 (9.1)	464 (7.3)	0.017
Congestive heart failure	28 063 (17.0)	6452 (28.6)	<0.001	9266 (8.6)	1300 (12.7)	<0.001	8076 (23.6)	1809 (30.2)	<0.001	10 721 (45.3)	3343 (52.7)	<0.001	10 721 (45.3)	3343 (52.7)	<0.001
Peripheral vascular disease	8059 (4.9)	1867 (8.3)	<0.001	3925 (3.7)	635 (6.2)	<0.001	2053 (6.0)	468 (7.8)	0.002	2081 (8.8)	763 (12.0)	<0.001	2081 (8.8)	763 (12.0)	<0.001
Chronic pulmonary disease	17 866 (10.8)	3833 (17.0)	<0.001	9539 (8.9)	1329 (13.0)	<0.001	4155 (12.1)	1045 (17.5)	<0.001	4172 (17.6)	1458 (23.0)	<0.001	4172 (17.6)	1458 (23.0)	<0.001
Chronic kidney disease	9496 (5.8)	2828 (12.6)	<0.001	3924 (3.7)	727 (7.1)	<0.001	2352 (6.9)	756 (12.6)	<0.001	3221 (13.6)	1346 (21.2)	<0.001	3221 (13.6)	1346 (21.2)	<0.001
Liver disease	1462 (0.9)	240 (1.1)	0.120	824 (0.8)	95 (0.9)	0.305	294 (0.9)	71 (1.2)	0.168	344 (1.5)	74 (1.2)	0.226	344 (1.5)	74 (1.2)	0.226
Anemia	10 506 (6.4)	2832 (12.6)	<0.001	3249 (3.0)	622 (6.1)	<0.001	2781 (8.1)	728 (12.2)	<0.001	4476 (18.9)	1483 (23.4)	<0.001	4476 (18.9)	1483 (23.4)	<0.001
Atrial fibrillation	12 878 (7.8)	3479 (15.4)	<0.001	4336 (4.0)	816 (8.0)	<0.001	3632 (10.6)	957 (16.0)	<0.001	4911 (20.8)	1705 (26.9)	<0.001	4911 (20.8)	1705 (26.9)	<0.001
Coagulopathy	4293 (2.6)	848 (3.8)	<0.001	1341 (1.3)	173 (1.7)	0.023	971 (2.8)	178 (3.0)	0.713	1981 (8.4)	497 (7.8)	0.459	1981 (8.4)	497 (7.8)	0.459
Collagen vascular disease	2931 (1.8)	569 (2.5)	<0.001	1675 (1.6)	184 (1.8)	0.288	683 (2.0)	152 (2.5)	0.201	572 (2.4)	233 (3.7)	0.001	572 (2.4)	233 (3.7)	0.001
Drug abuse	4817 (2.9)	804 (3.6)	0.002	3064 (2.9)	377 (3.7)	0.006	1039 (3.0)	209 (3.5)	0.258	714 (3.0)	217 (3.4)	0.386	714 (3.0)	217 (3.4)	0.386
Fluid/electrolyte disorders	20 705 (12.5)	4097 (18.2)	<0.001	8201 (7.7)	1032 (10.1)	<0.001	8182 (15.1)	917 (15.3)	0.821	7322 (31.0)	2149 (33.9)	0.016	7322 (31.0)	2149 (33.9)	0.016

(Continued)

Table 1. Continued

Characteristics	Overall			LOS 1 to 3 d			30-d Readmission			LOS 4 to 5 d			LOS >5 d		
	No	Yes	P Value	No	Yes	P Value	No	Yes	P Value	No	Yes	P Value	No	Yes	P Value
Obesity	22 433 (13.6)	2902 (12.9)	0.111	14 366 (13.4)	1259 (12.3)	0.129	4628 (13.5)	772 (12.9)	0.463	3439 (14.5)	870 (13.7)	0.374			
Other neurological disorders	4791 (2.9)	1037 (4.6)	<0.001	2223 (2.1)	331 (3.2)	<0.001	1185 (3.5)	278 (4.6)	0.014	1384 (5.9)	429 (6.8)	0.122			
Median household income			<0.001			0.009			0.011			0.557			
First quartile	45 601 (28.2)	6801 (30.7)		28 807 (27.4)	2989 (29.7)		9777 (29.1)	1834 (31.2)		7027 (30.3)	1978 (31.9)				
Second quartile	42 951 (26.5)	6003 (27.1)		27 946 (26.6)	2756 (27.4)		8888 (26.4)	1639 (27.9)		6117 (26.4)	1608 (25.9)				
Third quartile	39 131 (24.2)	5113 (23.1)		25 613 (24.4)	2317 (23.1)		8090 (24.0)	1403 (23.8)		5427 (23.4)	1393 (22.5)				
Fourth quartile	34 165 (21.1)	4222 (19.1)		22 659 (21.6)	1989 (19.8)		6884 (20.5)	1009 (17.1)		4621 (19.9)	1225 (19.7)				
Primary payer			<0.001			<0.001			<0.001			<0.001			<0.001
Medicare	59 249 (35.9)	11 581 (51.4)		33 937 (31.7)	4618 (45.2)		13 858 (40.5)	3113 (52.1)		11 453 (48.4)	3849 (60.7)				
Medicaid	12 619 (7.6)	2225 (9.9)		7639 (7.1)	975 (9.6)		2881 (8.4)	623 (10.4)		2099 (8.9)	627 (9.9)				
Private including HMO	65 646 (39.8)	5970 (26.5)		46 446 (43.4)	3235 (31.7)		12 291 (35.9)	1507 (25.2)		6910 (29.2)	1228 (19.4)				
Self-pay/no charge/other	27 510 (16.7)	2757 (12.2)		19 101 (17.8)	1381 (13.5)		5220 (15.2)	737 (12.3)		3189 (13.5)	639 (10.1)				
Index STEMI presentation/treatment															
Weekend admission	48 189 (29.2)	6272 (27.8)	0.016	31 794 (29.7)	2875 (28.2)	0.083	10 326 (30.1)	1811 (30.3)	0.908	6070 (25.7)	1587 (25.0)	0.548			
Cardiogenic shock	11 189 (6.8)	2532 (11.2)	<0.001	1847 (1.7)	247 (2.4)	0.003	2611 (7.6)	546 (9.1)	0.023	6723 (28.4)	1738 (27.4)	0.387			
Cardiac arrest	6675 (4.0)	1030 (4.6)	0.058	1987 (1.9)	213 (2.1)	0.366	1672 (4.9)	274 (4.6)	0.624	3017 (12.8)	543 (8.6)	<0.001			
IABP	13 261 (8.0)	2818 (12.5)	<0.001	2193 (2.0)	306 (3.0)	<0.001	4167 (12.2)	770 (12.9)	0.398	6901 (29.2)	1742 (27.5)	0.121			
PLVAD	565 (0.3)	114 (0.5)	0.041	86 (0.1)	12 (0.1)	0.484	100 (0.3)	15 (0.3)	0.750	380 (1.6)	87 (1.4)	0.451			
Hospital characteristics															
Hospital teaching status			0.210			0.011			0.055			0.661			
Teaching	88 606 (53.7)	11 905 (52.8)		55 994 (52.3)	5083 (49.8)		19 335 (56.5)	3228 (54.0)		13 277 (56.1)	3595 (56.7)				
Nonteaching	76 418 (46.3)	10 627 (47.2)		51 129 (47.7)	5126 (50.2)		14 915 (43.5)	2753 (46.0)		10 374 (43.9)	2747 (43.3)				
Hospital location			<0.001			0.193			0.449			0.037			
Rural	85 571 (51.9)	11 146 (49.5)		56 907 (53.1)	5293 (51.8)		17 207 (50.2)	2945 (49.2)		11 458 (48.4)	2907 (45.8)				
Urban	79 453 (48.1)	11 387 (50.5)		50 216 (46.9)	4916 (48.2)		17 044 (49.8)	3036 (50.8)		12 192 (51.6)	3434 (54.2)				
Hospital bed size			0.019			0.399			0.536			0.222			
Small	11 889 (7.2)	1399 (6.2)		8081 (7.5)	702 (6.9)		2302 (6.7)	363 (6.1)		1506 (6.4)	334 (5.3)				
Medium	36 686 (22.2)	4920 (21.8)		24 707 (23.1)	2426 (23.8)		7356 (21.5)	1239 (20.7)		4623 (19.5)	1254 (19.8)				
Large	116 449 (70.6)	16 213 (72.0)		74 335 (69.4)	7081 (69.4)		24 593 (71.8)	4379 (73.2)		17 521 (74.1)	4753 (75.0)				

(Continued)

Table 1. Continued

Characteristics	Overall		LOS 1 to 3 d		LOS 4 to 5 d		LOS >5 d	
	No	Yes	No	Yes	No	Yes	No	Yes
		P Value		P Value		P Value		P Value
Disposition								
Home	147 108 (89.1)	17 367 (77.1)	102 366 (95.6)	9219 (90.3)	29 771 (86.9)	4697 (78.5)	14 971 (63.3)	3450 (54.4)
Facility [§]	16 908 (10.2)	4950 (22.0)	3918 (3.7)	854 (8.4)	4385 (12.8)	1233 (20.6)	8605 (36.4)	2863 (45.1)
AMA/unknown	1008 (0.6)	215 (1.0)	838 (0.8)	136 (1.3)	95 (0.3)	51 (0.9)	75 (0.3)	29 (0.5)

AMA indicates against medical advice; AW, anterior wall; CABG, coronary artery bypass grafting; HMO, health maintenance organization; IABP, intra-aortic balloon pump; LOS, length of stay; PCI, percutaneous coronary intervention; PLVAD, percutaneous left ventricular assist device; SE, standard error; and STEMI, ST-segment–elevation myocardial infarction.

[†]Values are presented as number (percentage) of patients unless otherwise indicated.
[‡]Survey-specific linear regression was performed.
[§]Rao-Scott chi-square test was used for all statistical tests unless stated otherwise.
[¶]Facility includes skilled nursing facility, intermediate care facility, and inpatient rehabilitation facility.

the 4-day LOS cohort, 16.3% in the 5-day LOS cohort, and 19.5% in the >5-day LOS cohort ($P<0.001$) (Figure 2B). Very short LOS was associated with reduced risk of adjusted 30-day readmission in both the AW STEMI group (adjusted HR, 0.84; 95% CI, 0.78–0.91) and the NAW STEMI group (adjusted HR, 0.87; 95% CI, 0.83–0.92) compared with 3-day LOS. Patients with LOS of 4 days, 5 days, and >5 days showed incrementally higher risk of adjusted 30-day readmission in both the AW STEMI group (adjusted HR, 1.26 [95% CI, 1.17–1.36]; 1.42 [95% CI, 1.30–1.55]; and 1.50 [95% CI, 1.39–1.63], respectively) and the NAW STEMI group (adjusted HR, 1.19 [95% CI, 1.11–1.27]; 1.47 [95% CI, 1.34–1.60]; and 1.46 [95% CI, 1.37–1.57], respectively) (Figure 3, Tables S3 through S8).

Thirty-Day Readmission Mortality, Reinfarction, and Repeat Revascularization by LOS

The 30-day mortality rates during readmission were 0.2% in the short LOS cohort, 0.4% in the medium LOS cohort, and 1.3% in the long LOS cohort among the AW STEMI group ($P<0.001$), and 0.1% in the short LOS cohort, 0.4% in the medium LOS cohort, and 0.9% in the long LOS cohort among the NAW STEMI group ($P<0.001$). The 30-day mortality rates for both the AW STEMI group and the NAW STEMI group stratified by more detailed LOS cohorts are shown in Figure 2C and 2D. In the AW STEMI group, the rate of 30-day mortality was the lowest in the 3-day LOS cohort, showing a U-shaped risk distribution (Figure 3 and 4). Very short LOS after AW STEMI was associated with significantly higher risk of adjusted 30-day mortality compared with 3-day LOS (adjusted HR, 1.92; 95% CI, 1.16–3.16). However, the risk of adjusted 30-day mortality increased progressively with increasing LOS (adjusted HR: 4-day LOS [versus 3-day LOS], 1.80 [95% CI, 1.06–3.04]; 5-day LOS, 2.32 [95% CI, 1.44–3.73]; and >5-day LOS, 3.45 [95% CI, 2.22–5.36]) in the AW STEMI group. In the NAW STEMI group, the risk of adjusted 30-day mortality was not significantly different in the very short LOS cohort (adjusted HR, 0.71; 95% CI, 0.48–1.06) versus the 3-day LOS cohort, but the risk of adjusted 30-day mortality sequentially increased with longer LOS (adjusted HR: 4-day LOS [versus 3 day LOS], 1.52 [95% CI, 1.00–2.30]; 5-day LOS, 1.76 [95% CI, 1.06–2.93]; and >5-day LOS, 2.30 [95% CI, 1.45–3.65]).

The 30-day reinfarction rates were 4.6% in the short LOS cohort, 7.8% in the medium LOS cohort, and 10.0% in the long LOS cohort among the AW STEMI group ($P<0.001$), and 3.8% in the short LOS cohort, 6.1% in the medium LOS cohort, and 8.0% in the long LOS cohort among the NAW STEMI group ($P<0.001$).

Table 2. Baseline Characteristics for Patients Discharged Alive After Index Hospitalization with STEMI in Nonanterior Wall

Characteristics	Overall			LOS 1 to 3 d			30-d Readmission			LOS 4 to 5 d			LOS >5 d		
	No	Yes	P Value	No	Yes	P Value	No	Yes	P Value	No	Yes	P Value	No	Yes	P Value
Patients, No.	317 076* (90.1)	34 883 (9.9)		238 624 (92.3)	20 040 (7.7)		47 395 (86.6)	7310 (13.4)		31 058 (80.5)	7533 (19.5)				
Patient characteristics															
Age, mean (SE), y	60.9 (0.1)	64.4 (0.1)	<0.001†	59.7 (0.1)	62.2 (0.2)	<0.001†	63.6 (0.1)	66.3 (0.3)	<0.001†	65.9 (0.1)	68.3 (0.3)	<0.001†			<0.001†
Age group, y			<0.001†			<0.001†			<0.001			<0.001			<0.001
<50	56 533 (17.8)	4861 (13.9)		46 821 (19.6)	3491 (17.4)		6627 (14.0)	833 (11.4)		8085 (9.9)	538 (7.1)				
50 to 64	144 000 (45.4)	12 817 (36.7)		113 218 (47.4)	8028 (40.1)		19 283 (40.7)	2420 (33.1)		11 500 (37.0)	2368 (31.4)				
≥65	116 544 (36.8)	17 205 (49.3)		78 585 (32.9)	8520 (42.5)		21 486 (45.3)	4058 (55.5)		16 473 (0.53)	4627 (61.4)				
Women	87 055 (27.5)	12 980 (37.2)	<0.001	59 996 (25.1)	5521 (33.1)	<0.001	16 024 (33.8)	3065 (41.9)	<0.001	11 034 (35.5)	3282 (43.6)	<0.001			<0.001
Smoking history	165 955 (52.3)	16 289 (46.7)	<0.001	130 523 (54.7)	10 113 (50.5)	<0.001	22 398 (47.3)	3192 (43.7)	0.002	13 034 (42.0)	2985 (39.6)	0.053			
Hypertension	204 951 (64.6)	24 543 (70.4)	<0.001	151 781 (63.6)	13 912 (69.4)	<0.001	31 918 (67.3)	5274 (72.1)	<0.001	21 252 (68.4)	5357 (71.1)	0.016			
Diabetes mellitus	74 376 (23.5)	10 130 (29.0)	<0.001	52 890 (22.2)	5449 (27.2)	<0.001	12 590 (26.6)	2279 (31.2)	<0.001	8897 (28.6)	2402 (31.9)	0.004			
Dyslipidemia	189 949 (59.9)	20 014 (57.4)	<0.001	145 164 (60.8)	11 911 (59.4)	0.038	27 933 (58.9)	4183 (57.2)	0.119	16 852 (54.3)	3920 (52.0)	0.061			
Known coronary artery disease	274 434 (86.6)	30 088 (86.3)	0.408	206 436 (86.5)	17 322 (86.4)	0.879	41 391 (87.3)	6317 (86.4)	0.233	26 607 (85.7)	6448 (85.6)	0.934			
Previous myocardial infarction	26 016 (8.2)	3117 (8.9)	0.015	19 196 (8.0)	1692 (8.4)	0.297	4117 (8.7)	714 (9.8)	0.093	2703 (8.7)	712 (9.5)	0.294			
Previous PCI	41 118 (13.0)	4895 (14.0)	0.004	30 853 (12.9)	2754 (13.7)	0.088	6080 (12.8)	1023 (14.0)	0.142	4185 (13.5)	1118 (14.8)	0.103			
Previous CABG	9875 (3.1)	1338 (3.8)	<0.001	6961 (2.9)	679 (3.4)	0.057	1721 (3.6)	282 (3.9)	0.594	1193 (3.8)	377 (5.0)	0.020			
Family history of coronary artery disease	42 565 (13.4)	3669 (10.5)	<0.001	34 591 (14.5)	2531 (12.6)	<0.001	5200 (11.0)	634 (8.7)	0.002	2773 (8.9)	505 (6.7)	<0.001			
Congestive heart failure	24 943 (7.9)	5895 (16.9)	<0.001	9634 (4.0)	1503 (7.5)	<0.001	5990 (12.6)	1619 (22.1)	<0.001	9319 (30.0)	2772 (36.8)	<0.001			
Peripheral vascular disease	20 194 (6.4)	3605 (10.3)	<0.001	12 438 (5.2)	1536 (7.7)	<0.001	4047 (8.5)	931 (12.7)	<0.001	3709 (11.9)	1138 (15.1)	<0.001			
Chronic pulmonary disease	40 035 (12.6)	6846 (19.6)	<0.001	25 818 (10.8)	3304 (16.5)	<0.001	7466 (15.8)	1572 (21.5)	<0.001	6750 (21.7)	1969 (26.1)	<0.001			
Chronic kidney disease	18 808 (5.9)	4513 (12.9)	<0.001	9624 (4.0)	1647 (8.2)	<0.001	4159 (8.8)	1099 (15.0)	<0.001	5025 (16.2)	1767 (23.5)	<0.001			
Liver disease	2883 (0.9)	478 (1.4)	<0.001	1803 (0.8)	235 (1.2)	<0.001	562 (1.2)	100 (1.4)	0.413	518 (1.7)	143 (1.9)	0.442			
Anemia	20 972 (6.6)	4780 (13.7)	<0.001	8928 (3.7)	1486 (7.4)	<0.001	5100 (10.8)	1240 (17.0)	<0.001	6944 (22.4)	2053 (27.3)	<0.001			
Atrial fibrillation	25 715 (8.1)	5038 (14.4)	<0.001	12 801 (5.4)	1695 (8.5)	<0.001	5933 (12.5)	1362 (18.6)	<0.001	6981 (22.5)	1981 (26.3)	<0.001			
Coagulopathy	7280 (2.3)	1204 (3.5)	<0.001	2899 (1.2)	294 (1.5)	0.082	1488 (3.1)	268 (3.7)	0.212	2893 (9.3)	642 (8.5)	0.267			
Collagen vascular disease	5857 (1.8)	915 (2.6)	<0.001	3965 (1.7)	422 (2.1)	0.010	1186 (2.5)	254 (3.5)	0.012	705 (2.3)	240 (3.2)	0.018			
Drug abuse	8306 (2.6)	991 (2.8)	0.161	6181 (2.6)	663 (3.3)	<0.001	1304 (2.8)	204 (2.8)	0.933	820 (2.6)	124 (1.6)	0.001			

(Continued)

Table 2. Continued

Characteristics	Overall			LOS 1 to 3 d			LOS 4 to 5 d			LOS >5 d		
	No	Yes	P Value	No	Yes	P Value	No	Yes	P Value	No	Yes	P Value
	30-d Readmission											
Fluid/electrolyte disorders	33 047 (10.4)	5801 (16.6)	<0.001	16 251 (6.8)	1738 (8.7)	<0.001	6839 (14.4)	1366 (18.7)	<0.001	9957 (32.1)	2697 (35.8)	<0.001
Obesity	44 435 (14.0)	4886 (14.0)	0.982	32 872 (13.8)	2695 (13.4)	0.483	6770 (14.3)	1014 (13.9)	0.631	4794 (15.4)	1177 (15.6)	0.822
Other neurological disorders	8686 (2.7)	1597 (4.6)	<0.001	5182 (2.2)	714 (3.6)	<0.001	1625 (3.4)	314 (4.3)	0.026	1880 (6.1)	569 (7.6)	0.026
Median household income			<0.001			<0.001			0.109			0.235
First quartile	91 316 (29.3)	10 926 (31.9)		67 466 (28.8)	6 1162 (31.3)		14 530 (31.2)	2386 (33.2)		9320 (30.6)	2379 (32.1)	
Second quartile	83 375 (26.8)	9046 (26.4)		63 116 (26.9)	5199 (26.4)		12 159 (26.1)	1823 (25.4)		8100 (26.6)	2024 (27.3)	
Third quartile	76 278 (24.5)	8163 (23.8)		57 915 (24.7)	4702 (23.9)		10 977 (23.6)	1729 (24.1)		7386 (24.2)	1732 (23.4)	
Fourth quartile	60 361 (19.4)	6150 (17.9)		45 809 (19.6)	3634 (18.4)		8878 (19.1)	1241 (17.3)		5673 (18.6)	1275 (17.2)	
Primary payer			<0.001			<0.001			<0.001			<0.001
Medicare	121 138 (38.2)	18 413 (52.8)		82 427 (34.5)	9219 (46.0)		22 094 (46.6)	4363 (59.7)		16 618 (53.5)	4831 (64.1)	
Medicaid	21 603 (6.8)	2926 (8.4)		15 700 (6.6)	1651 (8.2)		3456 (7.3)	603 (8.2)		2447 (7.9)	671 (8.9)	
Private including HMO	122 511 (38.6)	9529 (27.3)		99 520 (41.7)	6463 (32.3)		14 681 (31.0)	1619 (22.1)		8309 (26.8)	1448 (19.2)	
Self-pay/no charge/other	51 824 (16.3)	4015 (11.5)		40 977 (17.2)	2706 (13.5)		7164 (15.1)	725 (9.9)		3683 (11.9)	583 (7.7)	
Index STEMI presentation/treatment												
Weekend admission	90 651 (28.6)	9770 (28.0)	0.219	69 034 (28.9)	5665 (28.3)	0.304	13 662 (28.8)	2300 (31.5)	0.013	7955 (25.6)	1804 (23.9)	0.118
Cardiogenic shock	15 204 (4.8)	3038 (8.7)	<0.001	4546 (1.9)	533 (2.7)	<0.001	3641 (7.7)	703 (9.6)	0.003	7017 (22.6)	1801 (23.9)	0.213
Cardiac arrest	9423 (3.0)	1343 (3.8)	<0.001	3415 (1.4)	308 (1.5)	0.505	2188 (4.6)	317 (4.3)	0.590	3820 (12.3)	717 (9.5)	<0.001
IABP	11 736 (3.7)	2346 (6.7)	<0.001	2077 (0.9)	307 (1.5)	<0.001	3 3778 (7.1)	590 (8.1)	0.124	6282 (20.2)	1450 (19.2)	0.348
PLVAD	301 (0.1)	74 (0.2)	<0.001	41 (0.0)	8 (0.0)	0.109	62 (0.1)	5 (0.1)	0.305	198 (0.6)	60 (0.8)	0.398
Hospital characteristics												
Hospital teaching status			0.312			0.133			0.784			0.234
Teaching	166 974 (52.7)	18 158 (52.1)		124 444 (52.2)	10 217 (51.0)		25 442 (53.7)	3901 (53.4)		17 089 (55.0)	4040 (53.6)	
Nonteaching	150 102 (47.3)	16 725 (47.9)		114 179 (47.8)	9822 (49.0)		21 954 (46.3)	3410 (46.6)		13 969 (45.0)	3493 (46.4)	
Hospital location			<0.001			<0.001			0.698			0.019
Rural	167 549 (52.8)	17 352 (49.7)		128 909 (54.0)	10 295 (51.4)		23 502 (49.6)	3591 (49.1)		15 138 (48.7)	3466 (46.0)	
Urban	149 527 (47.2)	17 532 (50.3)		109 714 (46.0)	9744 (48.6)		23 893 (50.4)	3719 (50.9)		15 920 (51.3)	4068 (54.0)	
Hospital bed size			0.973			0.775			0.052			0.729
Small	22 403 (7.1)	2458 (7.0)		17 761 (7.4)	1446 (7.2)		2806 (5.9)	530 (7.2)		1836 (5.9)	482 (6.4)	
Medium	69 610 (22.0)	7699 (22.1)		53 459 (22.4)	4572 (22.8)		10 140 (21.4)	1675 (22.9)		6012 (19.4)	1452 (19.3)	

(Continued)

Table 2. Continued

Characteristics	Overall			LOS 1 to 3 d			30-d Readmission			LOS 4 to 5 d			LOS >5 d		
	No	Yes	P Value	No	Yes	P Value	No	Yes	P Value	No	Yes	P Value	No	Yes	P Value
	Large	225 064 (71.0)	24 727 (70.9)	<0.001	167 404 (70.2)	14 021 (70.0)	<0.001	34 450 (72.7)	5106 (69.8)	<0.001	23 210 (74.7)	5599 (74.3)	<0.001	18 627 (60.0)	3812 (50.6)
Disposition															
Home	288 522 (91.0)	27 786 (79.7)		228 831 (95.9)	18 249 (91.1)		41 064 (86.6)	5725 (78.3)		18 627 (60.0)	3812 (50.6)		12 326 (39.7)	3676 (48.8)	
Facility [§]	26 610 (8.4)	6741 (19.3)		8113 (3.4)	1526 (7.6)		6171 (13.0)	1539 (21.1)		105 (0.3)	46 (0.6)		105 (0.3)	46 (0.6)	
AMA/unknown	1945 (0.6)	357 (1.0)		1679 (0.7)	265 (1.3)		161 (0.3)	46 (0.6)		105 (0.3)	46 (0.6)		105 (0.3)	46 (0.6)	

AMA indicates against medical advice; CABG, coronary artery bypass grafting; HMO, health maintenance organization; IABP, intra-aortic balloon pump; LOS, length of stay; PCI, percutaneous coronary intervention; PLVAD, percutaneous left ventricular assist device; SE, standard error; and STEMI, ST-segment–elevation myocardial infarction.

*Values are presented as number (percentage) of patients unless otherwise indicated.

[†]Survey-specific linear regression was performed.

[‡]Rao-Scott chi-square test was used for all statistical tests unless stated otherwise.

[§]Facility includes skilled nursing facility, intermediate care facility, and inpatient rehabilitation facility.

The 30-day reinfarction rates for both the AW and the NAW STEMI groups stratified by the detailed LOS cohorts are shown in Figure 2E and 2F. The risk of adjusted 30-day reinfarction increased progressively with increasing LOS in both the AW and the NAW STEMI groups (Figure 3).

The 30-day revascularization rates were 2.5% in the short LOS cohort, 3.0% in the medium LOS cohort, and 2.6% in the long LOS cohort among the AW STEMI group ($P=0.021$), and 2.7% in the short LOS cohort, 3.3% in the medium LOS cohort, and 2.7% in the long LOS cohort among the NAW STEMI group ($P<0.001$). The 30-day repeat revascularization rates from more detailed stratification of LOS are shown in Figure 2G and 2H. There was no significant difference in the risk for adjusted 30-day repeat revascularization among different LOS cohorts versus the 3-day LOS cohort in both the AW STEMI and the NAW STEMI groups.

The 30-day MACE rates were 5.8% in the short LOS cohort, 9.5% in the medium LOS cohort, and 11.9% in the long LOS cohort among the AW STEMI group ($P<0.001$), and 5.0% in the short LOS cohort, 7.8% in the medium LOS cohort, and 9.9% in the long LOS cohort among the NAW STEMI group ($P<0.001$). The 30-day MACE rates for both the AW and the NAW STEMI groups stratified by the detailed LOS cohorts are shown in Figure 2I and 2J. The risk of adjusted 30-day MACE increased progressively with increasing LOS in both the AW and the NAW STEMI groups (Figure 3).

Total Costs by LOS and Predictors of Total Cost

Hospital costs over 30 days after index hospitalization after primary PCI for STEMI according to the LOS are shown in Table 3. The median cumulative costs from index hospitalization for PCI and 30-day readmission were \$20 050 (interquartile range, \$15 494–\$27 463) in patients with AW STEMI and \$18 995 (interquartile range, \$14 790–\$25 787) in patients with NAW STEMI ($P<0.001$). The cumulative costs were also increased in the longer LOS groups compared with the very short LOS group regardless of the location of infarct ($P<0.001$ and $P<0.001$, respectively).

From the multivariable hierarchical regression analysis, very short LOS was found to be associated with a 4.3% decrease in 30-day total cost in the AW STEMI group and a 5.0% decrease in the NAW STEMI group versus 3-day LOS. Among patients with AW STEMI, 4-day LOS, 5-day LOS, and >5-day LOS were all found to be associated with increased total costs (4.7%, 8.6%, and 19.0% increase, respectively; $P<0.001$ for all) versus 3-day

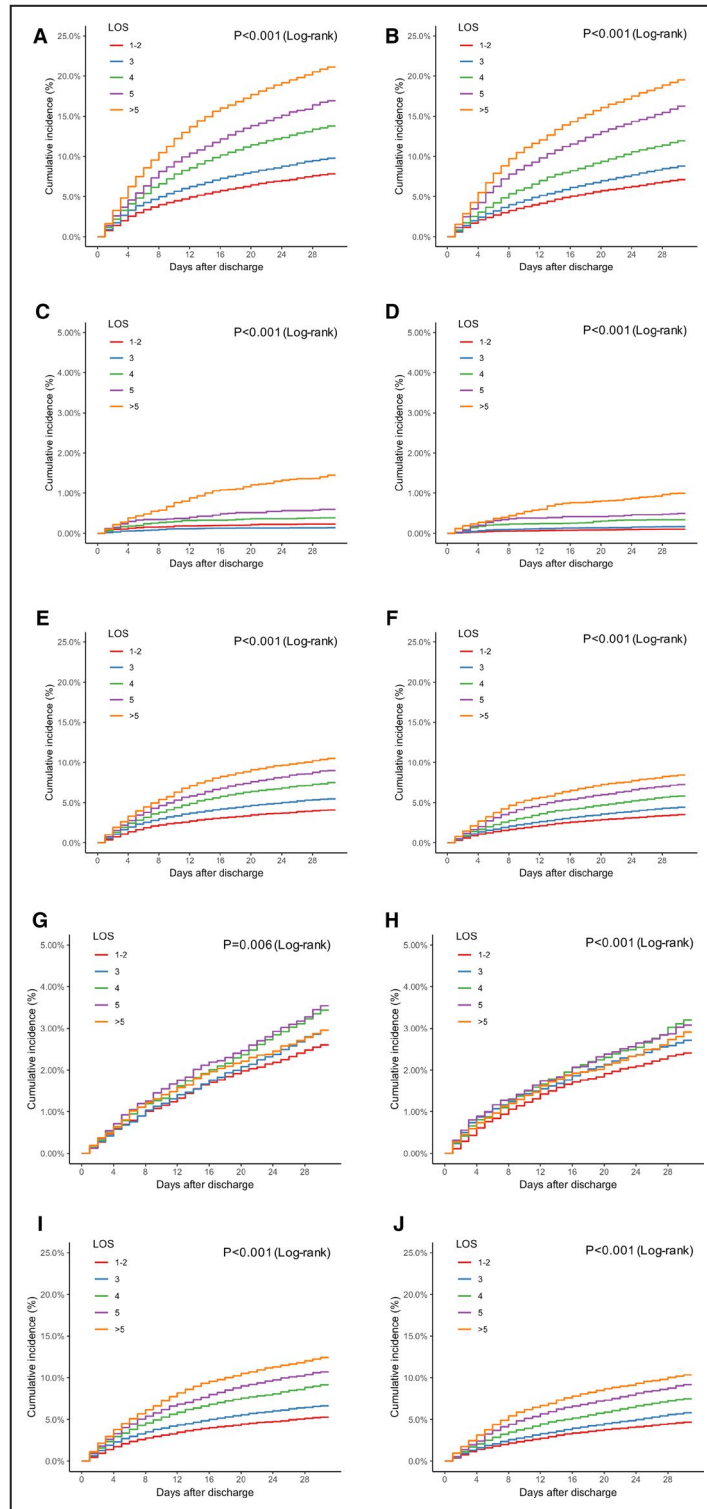


Figure 2. Cumulative rates of 30-day readmission, 30-day mortality, 30-day reinfarction, 30-day repeat revascularization, and 30-day major adverse cardiac events (MACE) according to hospital length of stay (LOS) and infarct location.

Data show unadjusted 30-day readmission in anterior wall (AW) ST-segment-elevation myocardial infarction (STEMI) (A) and non-AW STEMI (B), 30-day readmission mortality in AW STEMI (C) and non-AW STEMI (D), 30-day reinfarction in AW STEMI (E) and non-AW STEMI (F), 30-day repeat revascularization in AW STEMI (G) and non-AW STEMI (H), and 30-day MACE in AW STEMI (I) and non-AW STEMI (J).

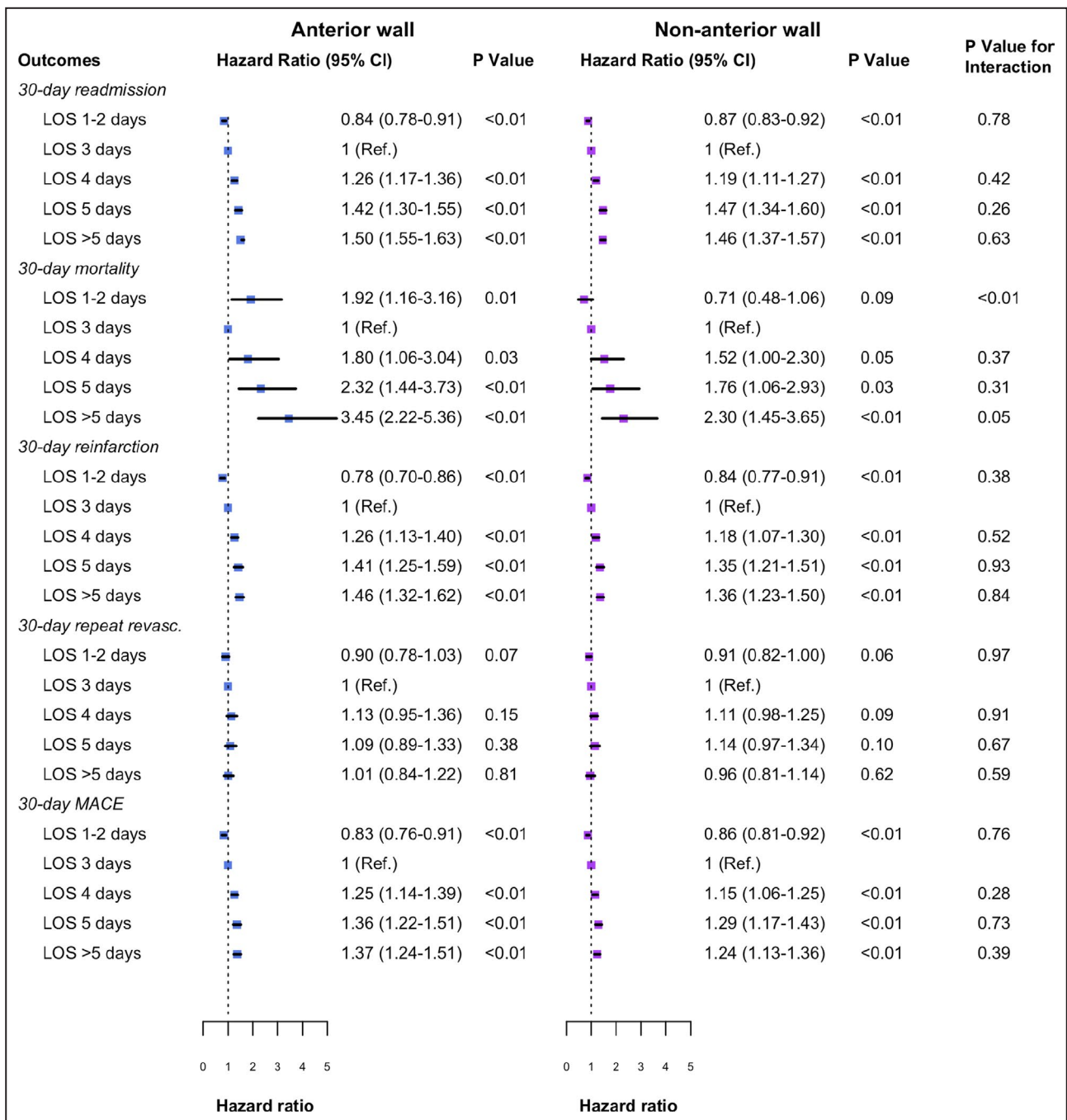


Figure 3. Forestplot of adjusted risk of 30-day readmission, 30-day mortality, 30-day reinfarction, 30-day repeat revascularization, and 30-day major adverse cardiac events (MACE) according to hospital length of stay (LOS) and infarct location. Adjusted covariates for each clinical outcome can be found in the supplemental material.

LOS (Table 4). Similarly, 4-day LOS, 5-day LOS, and >5-day LOS were associated with increased total costs (5.8%, 10.7%, and 22.3% increase, respectively; $P < 0.001$ for all) compared with 3-day LOS in the NAW STEMI cohort. The 30-day readmission was a significant predictor of increased total costs in both the AW STEMI group (17.5% increase, $P < 0.001$) and the NAW STEMI group (18.7% increase, $P < 0.001$).

DISCUSSION

In this large, contemporary, all-payer observational analysis of the NRD, we have presented several noteworthy findings for patients with STEMI who underwent primary PCI. First, very short LOS after primary PCI for STEMI was associated with significantly less 30-day readmission with reduced overall costs compared with more traditional, longer LOS in all STEMI

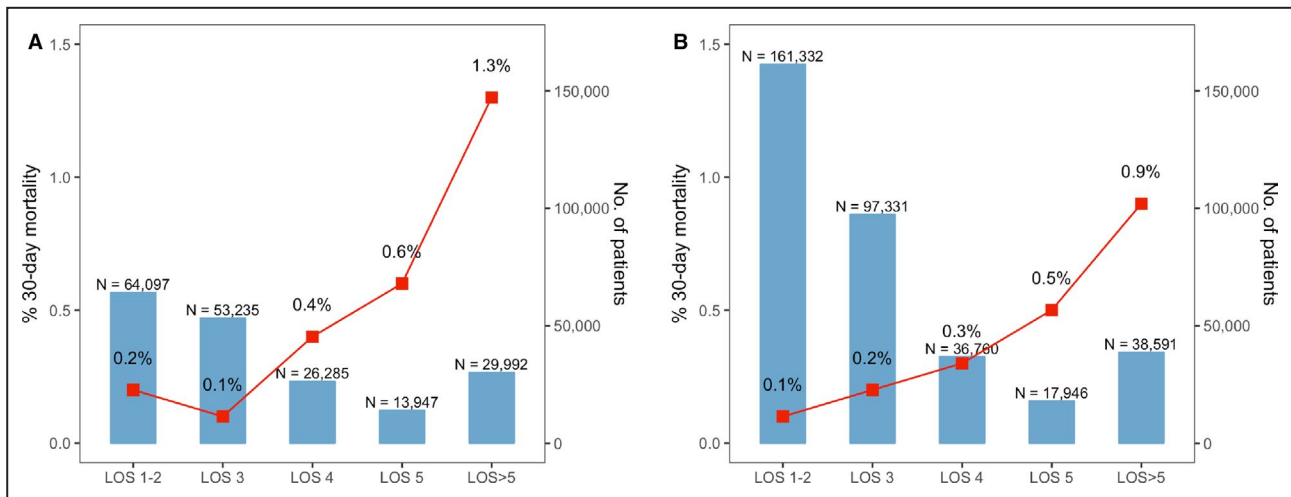


Figure 4. Plot of 30-day mortality according to hospital length of stay (LOS).

A, Thirty-day readmission mortality rate in patients with anterior wall (AW) ST-segment–elevation myocardial infarction (STEMI) (red points). **B**, Thirty-day readmission mortality rate in patients with non-AW STEMI (red points). Box plot shows total number of patients in each LOS group.

groups. Second, very short LOS appeared to be associated with higher 30-day readmission mortality rate compared with an LOS of at least 3 days in patients with AW STEMI, while very short LOS was associated with similar 30-day readmission mortality to 3-day LOS in patients with NAW STEMI. Third, rates of 30-day reinfarction, repeat revascularization rate, and MACE were the lowest in the very short LOS cohort.

Reducing hospital LOS has become a top priority in the past decade for our healthcare systems in the United States.^{21,22} Hospitalization with an average LOS of 4.5 days is estimated to cost the healthcare industry \$377.5 billion annually, and longer LOS has contributed greatly to these rising healthcare costs.²³ Optimizing and reducing LOS improves financial, operational, and clinical outcomes by preventing unnecessary hospital stays and decreasing the costs of care for a patient in various conditions.^{24,25} With recent advances in medical therapy and various therapeutic modalities, outcomes after STEMI have steadily improved over the past several years.^{1,26} With improving outcomes, there has been a growing interest in shortening LOS and assessing feasibility of early discharge after primary PCI for STEMI.^{27,28} We previously reported that short LOS (1–3 days) resulted in similar 30-day outcomes compared with medium LOS (4–5 days) after primary PCI for STEMI in the Medicare population using the NCDR (National Cardiovascular Data Registry) from 2004 to 2009.⁹ However, very short LOS (1–2 days) was associated with worse 30-day mortality and 30-day MACE in this elderly population. In the current study, analyzing all comers, including younger population with more contemporary data from 2010 to 2014, we demonstrated that very short hospital stay is associated with significantly less 30-day readmission as well as

30-day MACE including reinfarction and repeat revascularization. Shorter LOS and lower readmission rates were associated with 4.3% to 5.0% reduction in overall costs compared with more traditional ≥ 3 day LOS. However, very short LOS in AW STEMI was associated with an ≈ 2 -fold increase in 30-day mortality, while very short LOS was not associated with any increase in adverse outcomes in the NAW STEMI group. In fact, very short LOS was associated with 13% reduction in readmission rates and an $\approx 5.0\%$ reduction in overall costs in comparison to 3-day LOS in the NAW STEMI cohort. Our data emphasize that a very early discharge strategy for low-risk patients can be safe and feasible, especially in those with NAW STEMI. However, more careful assessment is necessary for patients with AW STEMI before opting for very early discharge. Once patients with AW STEMI are readmitted after a very short LOS during the index hospitalization, they may need closer attention with their medical care as our study demonstrates a higher 30-day mortality rate once they are readmitted. Our finding is not surprising given the increased likelihood of developing heart failure, left ventricular thrombus, and other complications including ventricular septal wall defect and free wall rupture, with AW STEMI because of larger territory involved.^{29,30} This group of patients may require more time to optimize the medications, especially for potentially newly developed heart failure with reduced ejection fraction.

Despite recent studies demonstrating the safety of very early discharge after PCI,^{6–9,31} a significant portion of patients stay in the hospital ≥ 3 days in the real world as demonstrated in our study (58.2%). Studies performed before modernization of pharmacotherapy and interventional therapy have demonstrated risks of potential subacute complications up to 72 hours after

Table 3. Costs and Charges Over 30-d Postindex Hospitalization After STEMI Stratified by the Location of Infarct

Outcomes	Overall	LOS 1 to 2 d	LOS 3 d	LOS 4 d	LOS 5 d	LOS >5 d	P Value*
AWMI							
Patients, No.	187 556	64 098	53 234	26 284	13 947	29 993	
Charge (index PCI), \$	66 879 (48 942–96 268) [†]	56 799 (42 817–77 204)	61 581 (46 908–83 214)	69 536 (52 388–97 494)	79 591 (59 316–112 784)	110 719 (78 640–159 337)	<0.001
Cumulative charges (index PCI+30-d readmission), \$	69 617 (50 272–102 446)	58 425 (43 741–80 277)	64 619 (47 942–87 767)	72 866 (54 208–103 595)	84 665 (61 701–120 650)	118 599 (83 336–172 750)	<0.001
Cost (index PCI), \$	19 307 (15 150–25 711)	16 501 (13 377–20 710)	18 166 (14 782–22 651)	20 313 (16 329–26 019)	22 821 (18 146–29 422)	31 425 (23 511–42 431)	<0.001
Cumulative costs (index PCI+30-d readmission), \$	20 050 (15 494–27 463)	16 899 (13 609–21 627)	18 689 (15 069–23 809)	21 224 (16 890–27 804)	24 210 (19 049–31 868)	33 581 (24 883–46 152)	<0.001
Non-AWMI							
No. of patients	351 961	161 332	97 331	36 760	17 947	38 591	
Charge (index PCI), \$	64 020 (47 024–91 562)	55 873 (42 255–75 033)	61 566 (46 898–83 430)	73 157 (54 312–102 146)	84 796 (63 283–118 509)	119 856 (84 845–171 422)	<0.001
Cumulative charges (index PCI+30-d readmission), \$	66 174 (48 057–96 916)	57 370 (43 023–78 032)	63 462 (47 871–87 824)	76 762 (55 959–109 101)	90 277 (66 028–127 599)	126 772 (89 184–184 904)	<0.001
Cost (index PCI), \$	18 413 (14 506–24 358)	16 288 (13 201–20 329)	18 049 (14 630–22 707)	20 749 (16 520–26 712)	23 668 (18 782–30 667)	33 339 (24 581–45 087)	<0.001
Cumulative costs (index PCI+30-d readmission), \$	18 995 (14 790–25 787)	16 676 (13 411–21 068)	18 576 (14 914–23 869)	21 661 (16 992–28 570)	25 055 (19 562–33 109)	35 390 (25 985–48 214)	<0.001

AWMI indicates anterior wall myocardial infarction; LOS, length of stay; PCI, percutaneous coronary intervention; and STEMI, ST-segment-elevation myocardial infarction.

*Mann-Whitney-U Wilcoxon test was used in all comparisons.

[†]All values are shown as a median (interquartile range).

Table 4. Multivariate Regression Analysis to Assess the Association of LOS on Total Cost in Patients With STEMI Stratified by the Location of Infarct

Variable	AW STEMI			Non-AW STEMI		
	Beta*	95% CI	P Value	Beta*	95% CI	P Value
LOS (reference: 3 d)						
1 to 2 d	-0.043	-0.049 to -0.037	<0.001	-0.050	-0.055 to -0.046	<0.001
4 d	0.047	0.043-0.052	<0.001	0.058	0.055-0.062	<0.001
5 d	0.086	0.080-0.091	<0.001	0.107	0.102-0.112	<0.001
>5 d	0.190	0.185-0.196	<0.001	0.223	0.218-0.228	<0.001
30-d readmission	0.175	0.170-0.180	<0.001	0.187	0.183-0.191	<0.001
Age (reference: <50), y						
50 to 64	0.006	0.003-0.010	0.001	0.007	0.004-0.010	<0.001
>64	0.007	0.002-0.013	0.006	0.010	0.006-0.014	<0.001
Women (reference: men)	-0.018	-0.021 to -0.015	<0.001	-0.019	-0.022 to -0.017	<0.001
Diabetes mellitus	0.004	0.001-0.007	0.012	0.005	0.002-0.007	<0.001
Dyslipidemia	n/s			0.004	0.001-0.007	0.014
Previous MI	0.009	0.004-0.015	0.001	n/s		
Known coronary artery disease	0.008	0.002-0.013	0.005	0.008	0.003-0.012	0.001
Peripheral vascular disease	0.010	0.004-0.016	0.002	0.005	0.001-0.009	0.017
Chronic kidney disease	n/s			-0.010	-0.015 to -0.006	<0.001
Anemia	0.006	0.001-0.012	0.030	n/s		
Coagulopathy	0.031	0.023-0.040	<0.001	0.029	0.022-0.036	<0.001
Drug abuse	0.012	0.003-0.020	0.006	n/s		
Fluid/electrolyte disorders	0.012	0.007-0.017	<0.001	0.011	0.007-0.016	<0.001
Obesity	0.013	0.008-0.018	<0.001	0.010	0.006-0.013	<0.001
Cardiogenic shock	0.029	0.022-0.036	<0.001	0.029	0.024-0.035	<0.001
Cardiac arrest	0.050	0.042-0.057	<0.001	0.037	0.031-0.043	<0.001
IABP	0.077	0.071-0.084	<0.001	0.080	0.073 to 0.087	<0.001
PLVAD	0.288	0.262-0.314	<0.001	0.291	0.267-0.314	<0.001
Weekend admission	n/s			0.005	0.003-0.008	<0.001
Median household income (reference: first quartile)						
Second quartile	0.020	0.014-0.025	<0.001	0.021	0.015-0.026	<0.001
Third quartile	0.038	0.030-0.045	<0.001	0.035	0.028-0.041	<0.001
Fourth quartile	0.064	0.055-0.074	<0.001	0.064	0.055-0.073	<0.001
Primary payer (reference: Medicare)						
Medicaid	0.018	0.010-0.025	<0.001	0.011	0.005-0.017	<0.001
Private	0.015	0.010-0.020	<0.001	0.014	0.010-0.017	<0.001
Self-pay/no charge/others	0.002	-0.004 to 0.008	0.568	-0.002	-0.007 to 0.003	0.534
Hospital bed size (reference: small)						
Medium	-0.023	-0.050 to 0.003	0.078	-0.018	-0.043 to 0.007	0.156
Large	-0.033	-0.059 to -0.008	0.011	-0.031	-0.056 to -0.007	0.013
Disposition (reference: home)						
Facility	0.017	0.011-0.022	<0.001	0.010	0.006-0.015	<0.001
AMA/unknown	-0.010	-0.029 to 0.008	0.261	-0.009	-0.021 to -0.003	0.140
Year (per y)	0.008	0.003-0.014	0.004	0.008	0.003-0.013	0.004

AMA indicates against medical advice; AW, anterior wall; IABP, intra-aortic balloon pump; LOS, length of stay; MI, myocardial infarction; PLVAD, percutaneous left ventricular assist device; and STEMI, ST-segment-elevation myocardial infarction.

*Survey-specific multivariate linear regression model was created with an outcome of log-transformed cumulative cost including all predictors with $P < 0.1$ in the univariate analysis. Hospital ID was also included as a covariable for consideration of hospital fixed-year effect (insignificant contribution, not shown).

STEMI,³² which has become a foundation of our clinical practice for many years. However, recent studies including the current one demonstrate the safety of

early discharge in certain low-risk cohorts. A recent increase in the adoption of radial access certainly has contributed to a significant decrease in access

site complications and bleeding risk,³³ which, in turn, may contribute to improving in-hospital outcomes with shorter LOS.^{33–36} With a recent study showing a significant increase of transradial PCI from 2010 to 2012 in the United States,^{37,38} reduced readmission in the very short LOS cohort in our study may partially reflect more contemporary data in the current era of transradial PCI.

Since the implementation of the HRRP, there have been some controversies on the association of reduction in readmission rates and its impact on overall mortality.^{39,40} A study comprising Medicare beneficiaries with heart failure demonstrated that the implementation of the HRRP was associated with an 0.5% increase in 30-day mortality.^{41,42} Some studies have shown that 30-day readmission rate has a poor or even an inverse relationship with 30-day mortality.^{43,44} Pandey et al⁴⁵ demonstrated that the 30-day risk-adjusted readmission rates after acute myocardial infarction were not associated with 1-year mortality. In addition, Dharmarajan et al⁴⁶ reported that the reduction in 30-day readmission rate did not correlate with higher 30-day mortality rate in Medicare beneficiaries hospitalized for acute myocardial infarction. The inverse relationship of 30-day readmission and 30-day mortality in the AW STEMI group with very short LOS in our study demonstrates that 30-day readmission rate may not be the best metric for quality of care, especially for AW STEMI. More detailed studies are necessary to tease out the features that may predispose certain patients with STEMI who would be at risk of worse outcomes with very early discharge. Last, our study demonstrated that the total cumulative costs are the lowest in the very short LOS group in both the patients with AW and NAW STEMI, mostly as a result of significantly less index hospitalization cost with similar or fewer readmissions. Identifying proper cohorts with less likelihood of readmission despite shortening the LOS remains an important goal for future studies.

STUDY LIMITATIONS

The present study has the limitations inherent to nonrandomized observational studies. First, the data from the NRD include the sample designed to approximate the national distribution of representative hospital characteristics. Our study cohort was derived from approximately half sample of US hospitals, and as a result the study cohort can be either underrepresented or overrepresented by the sample. Our results cannot be considered completely generalizable among all states in the United States since the NRD includes only 22 states in the United States. However, there have been numerous

publications utilizing the NRD that validate the sampling design.^{15,47,48} Second, the study cohort from a large administrative data set can be subject to coding bias or possibly missing events or variables. Nevertheless, many studies have proven the validity of using administrative databases for risk-adjusted outcome evaluation.^{47,49,50} Third, some of the clinical parameters including vital signs (eg, blood pressure and heart rate), echocardiographic parameters (eg, ejection fraction), laboratory findings (eg, troponin-I and brain natriuretic peptide), or medications (eg, antiplatelets and heart failure medications) are not available for analysis in the NRD. Our study is intended to generate a hypothesis, and future studies are necessary to confirm our findings with more detailed information. Fourth, although we performed an appropriate statistical approach using validated risk models, there is no way to eliminate bias from the influence of unmeasured confounders given that the NRD is based on *ICD-9-CM* codes. Fifth, our study did not differentiate between STEMI with emergent PCI versus STEMI with delayed PCI during hospitalization. In addition, some of the readmissions may be attributable to staged PCI procedures, but the limitation of the database does not allow identification of these admissions. Sixth, our cost analyses did not consider the effects of differential mortality among different LOS cohorts. Finally, our 30-day mortality rate does not account for out-of-hospital deaths, which may underestimate the overall mortality rate.

CONCLUSIONS

This study examined short-term clinical outcomes and total costs according to LOS after STEMI stratified by the location of infarct. Our data show that very early discharge after primary PCI is safe and less costly in low-risk patients, especially those with NAW STEMI. For those with AW STEMI, care needs to be taken before opting for very early discharge given the potential increase in 30-day mortality. Very short LOS is associated with fewer readmissions, but if patients are readmitted, 30-day mortality is higher in those with AW STEMI. Further studies to better identify proper cohorts of patients with STEMI who are suitable for a very early discharge strategy are warranted. These efforts will hopefully lead to reduction in overall cost and improvement in overall quality and efficiency of care for patients with STEMI.

ARTICLE INFORMATION

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Disclosures

None.

Supplementary Materials

Tables S1–S8

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SUPPLEMENTAL MATERIAL

Table S1. International Classification of Diseases, Ninth Revision-Clinical Modification (ICD-9-CM) codes and Clinical Classification Software (CCS) codes for selected variables.

Percutaneous coronary intervention	0066,3601,3602,3605, 3606, 3607
Smoking	305.1, V15.82
Dyslipidemia	272.4
Previous myocardial infarction	412
Previous percutaneous coronary intervention	V45.82
Previous coronary artery bypass graft	V45.81
Family history of coronary artery disease	V17.3
Congestive heart failure	428.0
Known coronary artery disease	414.01
Pulmonary hypertension	416.0
Atrial fibrillation	427.31
Collagen vascular disease	357.1
Cardiogenic shock	785.51
Cardiac arrest	427.5
Intra-aortic balloon pump (IABP)	37.61
Percutaneous left ventricle assist device (PLVAD)	37.68

Table S2. Baseline Characteristics for Patients Discharged Alive After Index Hospitalization for STEMI Stratified by Length of Stay.

Characteristics	AW STEMI					NAW STEMI				
	Overall (N =	LOS<=3 days	LOS 4-5 days	LOS>5 days	P Value	Overall	LOS<=3 days	LOS 4-5 days	LOS>5 days	P Value
Number of admissions	187,557	117,332* (62.6)	40,232 (21.4)	29,993 (16.0)		351,960	258,663 (73.5)	54,706 (15.5)	38,591 (11.0)	
Patient characteristics										
Age, mean (SE), y	60.8 (0.1)	59.3 (0.1)	62.2 (0.1)	65.0 (0.2)	<0.001†	61.2 (0.1)	60.0 (0.1)	64.0 (0.1)	66.3 (0.1)	<0.001†
Age group, y					<0.001‡					<0.001
<50	36,759 (19.6)	25,384 (21.6)	73,13 (18.2)	4,062 (13.5)		61,394 (17.4)	50,312 (19.5)	7,459 (13.6)	3,623 (9.4)	
50-64	81,776 (43.6)	54,771 (46.7)	16,284 (40.5)	10,721 (35.7)		156,816 (44.6)	121,246 (46.9)	21,703 (39.7)	13,867 (35.9)	
≥65	69,022 (36.8)	37,177 (31.7)	16,635 (41.3)	15,210 (50.7)		133,750 (38.0)	87,105 (33.7)	25,544 (46.7)	21,101 (54.7)	
Female	49,028 (26.1)	26,346 (22.5)	12,247 (30.4)	10,435 (34.8)	<0.001	100,035 (28.4)	66,629 (25.8)	19,090 (34.9)	14,316 (37.1)	<0.001
Smoking history	87,696 (46.8)	57,820 (49.3)	18,129 (45.1)	11,747 (39.2)	<0.001	182,245 (51.8)	140,636 (54.4)	25,590 (46.8)	16,019 (41.5)	<0.001
Hypertension	116,083 (61.9)	71,383 (60.8)	25,379 (63.1)	19,321 (64.4)	<0.001	229,495 (65.2)	165,692 (64.1)	37,193 (68.0)	26,610 (69.0)	<0.001
Diabetes mellitus	44,515 (23.7)	25,958 (22.1)	10,425 (25.9)	8,132 (27.1)	<0.001	84,506 (24.0)	58,339 (22.6)	14,868 (27.2)	11,299 (29.3)	<0.001
Dyslipidemia	107,233 (57.2)	68,849 (58.7)	22,769 (56.6)	15,615 (52.1)	<0.001	209,963 (59.7)	157,075 (60.7)	32,115 (58.7)	20,773 (53.8)	<0.001
Known coronary artery disease	163,919 (87.4)	102,541 (87.4)	35,336 (87.8)	26,043 (86.8)	0.127	304,522 (86.5)	223,759 (86.5)	47,708 (87.2)	33,055 (85.7)	0.003
Previous myocardial infarction	12,807 (6.8) (6.8)	7,925 (6.8)	2,639 (6.6)	2,243 (7.5)	0.018	29,134 (8.3)	20,888 (8.1)	4,831 (8.8)	3,414 (8.8)	<0.001
Previous PCI	20,267 (10.8)	12,489 (10.6)	4,275 (10.6)	3,503 (11.7)	0.014	46,013 (13.1)	33,607 (13.0)	7,103 (13.0)	5,303 (13.7)	0.105
Previous CABG	2,048 (1.1)	1,126 (1.0)	452 (1.1)	469 (1.1)	<0.001	11,212 (3.2)	7,639 (3.0)	2,003 (3.7)	1,570 (4.1)	<0.001
Family history of coronary artery disease	24,785 (13.2)	17,183 (14.6)	4,979 (12.4)	2,622 (8.7)	<0.001	46,234 (13.1)	37,122 (14.4)	5,834 (10.7)	3,278 (8.5)	<0.001

Congestive heart failure	34,515 (18.4)	10,566 (9.0)	9,885 (24.6)	14,064 (46.9)	<0.001	30,838 (8.8)	11,137 (4.3)	7,609 (13.9)	12,091 (31.3)	<0.001
Peripheral vascular disease	9,925 (5.3)	4,560 (3.9)	2,521 (6.3)	2,844 (9.5)	<0.001	23,799 (6.8)	13,974 (5.4)	4,978 (9.1)	1,919 (12.6)	<0.001
Chronic pulmonary disease	21,699 (11.6)	10,868 (9.3)	5,201 (12.9)	5,630 (18.8)	<0.001	46,880 (13.3)	29,122 (11.3)	9,038 (16.5)	8,720 (22.6)	<0.001
Chronic kidney disease	12,324 (6.6)	4,650 (4.0)	3,107 (7.7)	4,567 (15.2)	<0.001	23,322 (6.6)	11,271 (4.4)	5,258 (9.6)	6,793 (17.6)	<0.001
Liver disease	1,702 (0.9)	919 (0.8)	365 (0.9)	418 (1.4)	<0.001	3,361 (1.0)	2,038 (0.8)	662 (1.2)	661 (1.7)	<0.001
Anemia	13,338 (7.1)	3,871 (3.3)	3,509 (8.7)	5,958 (19.9)	<0.001	25,752 (7.3)	10,414 (4.0)	6,341 (11.6)	8,997 (23.3)	<0.001
Atrial fibrillation	16,357 (8.7)	5,152 (4.4)	4,589 (11.4)	6,616 (22.1)	<0.001	30,753 (8.7)	14,496 (5.6)	7,295 (13.3)	8,962 (23.2)	<0.001
Coagulopathy	5,141 (2.7)	1,514 (1.3)	1,149 (2.9)	2,478 (8.3)	<0.001	8,484 (2.4)	3,193 (1.2)	1,756 (3.2)	3,535 (9.2)	<0.001
Collagen vascular disease	3,499 (1.9)	1,859 (1.6)	835 (2.1)	805 (2.7)	<0.001	6,772 (1.9)	4,387 (1.7)	1,440 (2.6)	945 (2.4)	<0.001
Drug abuse	5,621 (3.0)	3,441 (2.9)	1,249 (3.1)	931 (3.1)	0.456	9,296 (2.6)	6,845 (2.6)	1,507 (2.8)	944 (2.4)	0.276
Fluid/electrolyte disorders	24,803 (13.2)	9,234 (7.9)	6,098 (15.2)	9,471 (31.6)	<0.001	38,850 (11.0)	17,990 (7.0)	8,206 (15.0)	12,654 (32.8)	<0.001
Obesity	25,336 (13.5)	15,625 (13.3)	5,401 (13.4)	4,310 (14.4)	0.031	49,321 (14.0)	35,567 (13.8)	7,784 (14.2)	5,970 (15.5)	<0.001
Other neurological disorders	5,827 (3.1)	2,553 (2.2)	1,462 (3.6)	1,812 (6.0)	<0.001	10,284 (2.9)	5,896 (2.3)	1,939 (3.5)	2,449 (6.3)	<0.001
Median household income					<0.001					<0.001
First quartile	52,402 (28.5)	31,796 (27.6)	11,611 (29.4)	8,995 (30.6)		102,242 (29.6)	73,628 (29.0)	16,916 (31.5)	11,698 (30.9)	
Second quartile	48,955 (26.6)	30,702 (26.7)	10,528 (26.6)	7,725 (26.3)		92,421 (26.7)	68,315 (26.9)	13,982 (26.0)	10,124 (26.7)	
Third quartile	44,243 (24.0)	27,930 (24.3)	9,493 (24.0)	6,820 (23.2)		84,442 (24.4)	62,618 (24.7)	12,707 (23.7)	9,117 (24.1)	
Fourth quartile	38,387 (20.9)	24,648 (21.4)	7,893 (20.0)	5,846 (19.9)		66,512 (19.2)	49,444 (19.5)	10,119 (18.8)	6,949 (18.3)	
Primary payer					<0.001					<0.001

Medicare	70,830 (37.8)	38,556 (32.9)	16,972 (42.2)	15,302 (51.0)		139,552 (39.6)	91,646 (35.4)	26,457 (48.4)	21,449 (55.6)	
Medicaid	14,844 (7.9)	8,615 (7.3)	3,504 (8.7)	2,725 (9.1)		24,529 (7.0)	17,351 (6.7)	4,060 (7.4)	3,118 (8.1)	
Private including HMO	71,617 (38.2)	49,681 (42.3)	13,798 (34.3)	8,138 (27.1)		132,040 (37.5)	105,983 (41.0)	16,300 (29.8)	9,757 (25.3)	
Self-pay/no charge/other	30,266 (16.1)	20,481 (17.5)	5,958 (14.8)	3,827 (12.8)		55,839 (15.9)	43,683 (16.9)	7,890 (14.4)	4,266 (11.1)	
Index STEMI presentation/treatment										
Weekend admission	54,462 (29.0)	34,668 (29.5)	12,137 (30.2)	7,657 (25.5)	<0.001	100,421 (28.5)	74,700 (28.9)	15,962 (29.2)	9,759 (25.3)	<0.001
Cardiogenic shock	13,711 (7.3)	2,093 (1.8)	3,157 (7.8)	8,461 (28.2)	<0.001	18,241 (5.2)	5,079 (2.0)	4,344 (7.9)	8,818 (22.8)	<0.001
Cardiac arrest	7,705 (4.1)	2,200 (1.9)	1,945 (4.8)	3,560 (11.9)	<0.001	10,766 (3.1)	3,723 (1.4)	2,506 (4.6)	4,537 (11.8)	<0.001
IABP	16,078 (8.6)	2,499 (2.1)	4,937 (12.3)	8,642 (28.8)	<0.001	14,082 (4.0)	2,383 (0.9)	3,967 (7.3)	7,732 (20.0)	<0.001
PLVAD	680 (0.4)	98 (0.1)	115 (0.3)	467 (1.6)	<0.001	375 (0.1)	49 (0.0)	67 (0.1)	259 (0.7)	<0.001
Hospital characteristics										
Hospital teaching status					<0.001					<0.001
Teaching	100,512 (53.6)	61,078 (52.1)	22,563 (56.1)	16,871 (56.3)		185,133 (52.6)	134,662 (52.1)	29,342 (53.6)	21,129 (54.8)	
Nonteaching	87,045 (46.4)	56,255 (47.9)	17,669 (43.9)	13,121 (43.7)		166,827 (47.4)	124,001 (47.9)	25,364 (46.4)	17,462 (45.2)	
Hospital location					<0.001					<0.001
Rural	96,717 (51.6)	62,199 (53.0)	20,152 (50.1)	14,366 (47.9)		184,901 (52.5)	139,204 (53.8)	27,093 (49.5)	18,604 (48.2)	
Urban	90,840 (48.4)	55,133 (47.0)	20,080 (49.9)	15,627 (52.1)		167,059 (47.5)	119,459 (46.2)	27,613 (50.5)	19,987 (51.8)	
Hospital bed size					<0.001					<0.001
Small	13,289 (7.1)	8,783 (7.5)	2,665 (6.6)	1,841 (6.1)		24,861 (7.1)	19,207 (7.4)	3,336 (6.1)	2,318 (6.0)	
Medium	41,605 (22.2)	27,133 (23.1)	8,595 (21.4)	5,877 (19.6)		77,308 (22.0)	58,030 (22.4)	11,814 (21.6)	7,464 (19.3)	

Large	132,663 (70.7)	81,417 (69.4)	28,971 (72.0)	22,275 (74.3)		249,791 (71.0)	181,426 (70.1)	39,556 (72.3)	28,809 (74.7)	
Disposition					<0.001					<0.001
Home	164,476 (87.7)	111,587 (95.1)	34,468 (85.7)	18,421 (61.4)		316,308 (89.9)	247,080 (95.5)	46,789 (85.5)	22,439 (58.1)	
Facility 	21,858 (11.7)	4,773 (4.1)	5,617 (14.0)	11,468 (38.2)		33,350 (9.5)	9,639 (3.7)	7,710 (14.1)	16,001 (41.5)	
AMA/unknown	1,223 (0.7)	974 (0.8)	146 (0.4)	103 (0.3)		2,302 (0.7)	1,944 (0.8)	207 (0.4)	151 (0.4)	

AW STEMI, anterior wall ST-segment elevation myocardial infarction; NAW STEMI, non-anterior wall ST-segment elevation myocardial infarction; LOS, length of stay; SE, standard error; PCI, percutaneous coronary intervention; CABG, coronary artery bypass grafting; HMO, health maintenance organization; IABP, intra-aortic balloon pump; PLVAD, percutaneous left ventricular assist device; AMA, against medical advice.

*Values are presented as number (percentage) of patients unless otherwise indicated.

†Survey-specific linear regression was performed.

‡Rao-Scott χ^2 test was used for all statistical tests unless stated otherwise.

||Facility includes skilled nursing facility, intermediate care facility, and inpatient rehabilitation facility.

Table S3. Thirty-day Outcomes According to Length of Stay Stratified by Location of Infarct.

Outcome	LOS (Ref: 3 days)	AW STEMI				NAW STEMI				P for interaction
		Unadjusted HR (95% CI)	P value	Adjusted HR (95% CI)	P value	Unadjusted HR (95% CI)	P value	Adjusted HR (95% CI)	P value	
Readmission	1-2 days	0.79 (0.73-0.85)	<0.01	0.84 (0.78-0.91)	<0.01	0.80 (0.76-0.84)	<0.01	0.87 (0.83-0.92)	<0.01	0.78
	4 days	1.44 (1.33-1.55)	<0.01	1.26 (1.17-1.36)	<0.01	1.38 (1.29-1.47)	<0.01	1.19 (1.11-1.27)	<0.01	0.42
	5 days	1.78 (1.65-1.95)	<0.01	1.42 (1.30-1.55)	<0.01	1.92 (1.77-2.09)	<0.01	1.47 (1.34-1.60)	<0.01	0.26
	>5 days	2.30 (2.15-2.46)	<0.01	1.50 (1.39-1.63)	<0.01	2.36 (2.23-2.50)	<0.01	1.46 (1.37-1.57)	<0.01	0.63
Mortality	1-2 days	1.65 (1.01-2.68)	0.04	1.92 (1.16-3.16)	0.01	0.62 (0.42-0.92)	0.02	0.71 (0.48-1.06)	0.09	<0.01
	4 days	2.79 (1.65-4.71)	<0.01	1.80 (1.06-3.04)	0.03	2.06 (1.37-3.07)	<0.01	1.52 (1.00-2.30)	0.05	0.37
	5 days	4.35 (2.73-6.92)	<0.01	2.32 (1.44-3.73)	<0.01	3.06 (1.87-5.02)	<0.01	1.76 (1.06-2.93)	0.03	0.31
	>5 days	10.29 (6.94-15.27)	<0.01	3.45 (2.22-5.36)	<0.01	6.02 (4.23-8.57)	<0.01	2.30 (1.45-3.65)	<0.01	0.05
Reinfarction	1-2 days	0.74 (0.67-0.82)	<0.01	0.78 (0.70-0.86)	<0.01	0.78 (0.72-0.85)	<0.01	0.84 (0.77-0.91)	<0.01	0.38
	4 days	1.38 (1.24-1.55)	<0.01	1.26 (1.13-1.40)	<0.01	1.32 (1.20-1.46)	<0.01	1.18 (1.07-1.30)	<0.01	0.52
	5 days	1.67 (1.49-1.88)	<0.01	1.41 (1.25-1.59)	<0.01	1.66 (1.49-1.85)	<0.01	1.35 (1.21-1.51)	<0.01	0.93
	>5 days	1.97 (1.80-2.16)	<0.01	1.46 (1.32-1.62)	<0.01	1.95 (1.79-2.13)	<0.01	1.36 (1.23-1.50)	<0.01	0.84
Repeat Revascularization	1-2 days	0.88 (0.77-1.02)	0.08	0.90 (0.78-1.03)	0.12	0.88 (0.80-0.97)	0.01	0.91 (0.82-1.00)	0.06	0.97
	4 days	1.17 (0.98-1.40)	0.08	1.13 (0.95-1.36)	0.17	1.16 (1.03-1.31)	0.01	1.11 (0.98-1.25)	0.09	0.91
	5 days	1.14 (0.93-1.38)	0.21	1.09 (0.89-1.33)	0.41	1.20 (1.03-1.41)	0.02	1.14 (0.97-1.34)	0.10	0.67
	>5 days	1.07 (0.90-1.26)	0.46	1.01 (0.84-1.22)	0.91	1.01 (0.87-1.17)	0.93	0.96 (0.81-1.14)	0.62	0.59
MACE	1-2 days	0.79 (0.72-0.86)	<0.01	0.83 (0.76-0.91)	<0.01	0.80 (0.75-0.86)	<0.01	0.86 (0.81-0.92)	<0.01	0.76
	4 days	1.40 (1.26-1.54)	<0.01	1.25 (1.14-1.39)	<0.01	1.30 (1.20-1.42)	<0.01	1.15 (1.06-1.25)	<0.01	0.28
	5 days	1.65 (1.48-1.83)	<0.01	1.36 (1.22-1.51)	<0.01	1.62 (1.47-1.78)	<0.01	1.29 (1.17-1.43)	<0.01	0.73
	>5 days	1.93 (1.77-2.10)	<0.01	1.37 (1.24-1.51)	<0.01	1.84 (1.70-1.99)	<0.01	1.24 (1.13-1.36)	<0.01	0.39

AW STEMI, anterior wall ST-segment elevation myocardial infarction; NAW STEMI, non-anterior wall ST-segment elevation myocardial infarction; LOS, length of stay; HR, hazard ratio; CI, confidence interval.

*Univariate Cox proportional hazards regression model was created with an outcome of 30-day readmission for each covariate from Table 1 and the covariates with p values < 0.1 are listed.

†Multivariate Cox proportional hazards regression model was created with an outcome of 30-day readmission including all predictors with p values < 0.1 in the univariate analysis.

Table S4. Independent Predictors of 30-day Readmission After Index PCI with STEMI.

Variables	AW STEMI				NAW STEMI			
	Adjusted HR	95% CI (lower)	95% CI (higher)	P value	Adjusted HR	95% CI (lower)	95% CI (higher)	P value
LOS (Ref: 3 days)								
1-2 days	0.84	0.78	0.91	<0.01	0.87	0.83	0.92	<0.01
4 days	1.26	1.17	1.36	<0.01	1.19	1.11	1.27	<0.01
5 days	1.42	1.30	1.55	<0.01	1.47	1.34	1.60	<0.01
>5 days	1.50	1.39	1.63	<0.01	1.46	1.37	1.57	<0.01
Female	1.25	1.18	1.31	<0.01	1.22	1.17	1.28	<0.01
Hypertension	1.10	1.04	1.16	<0.01	1.09	1.04	1.14	<0.01
Diabetes mellitus	1.14	1.08	1.21	<0.01	1.16	1.11	1.21	<0.01
Congestive heart failure	1.17	1.11	1.24	<0.01	1.31	1.23	1.38	<0.01
Peripheral vascular disease	1.18	1.08	1.29	<0.01	1.17	1.09	1.25	<0.01
Chronic lung disease	1.26	1.18	1.35	<0.01	1.27	1.20	1.33	<0.01
Renal failure	1.38	1.28	1.49	<0.01	1.37	1.27	1.45	<0.01
Anemia	1.14	1.05	1.23	<0.01	1.21	1.14	1.29	<0.01
Atrial fibrillation	1.33	1.24	1.43	<0.01	1.26	1.18	1.32	<0.01
Drug abuse	1.30	1.15	1.48	<0.01	1.14	1.00	1.28	0.03
Other neuropathy	1.12	1.00	1.25	0.05	1.18	1.07	1.30	<0.01
Fluid/Electrolyte disorders	n/s				1.09	1.02	1.14	<0.01
Intra-aortic balloon pump	1.09	1.01	1.18	0.02	1.19	1.01	1.21	0.03
Hospital location, rural (Ref: urban)	0.94	0.89	0.99	0.03	0.93	0.88	0.97	<0.01
Disposition (Ref: home)								
Facility	1.22	1.13	1.31	<0.01	1.29	1.21	1.37	<0.01
AMA/others	1.80	1.45	2.24	<0.01	1.87	1.57	2.23	<0.01
Primary payer (Ref: Medicare)								
Medicaid	1.10	0.99	1.23	0.09	1.03	0.94	1.12	0.50
Private	0.72	0.66	0.78	<0.01	0.74	0.69	0.79	<0.01
Others	0.76	0.69	0.84	<0.01	0.70	0.65	0.76	<0.01
Median household income (Ref: 1 st quartile)								
2 nd quartile	0.98	0.92	1.05	0.65	0.94	0.89	0.98	0.03
3 rd quartile	0.92	0.86	0.99	0.02	0.94	0.88	0.98	0.02
4 th quartile	0.89	0.82	0.97	<0.01	0.89	0.83	0.94	<0.01
Age group, y (Ref: <50)								
50 to 64	0.99	0.92	1.07	0.85	0.95	0.88	1.00	0.09

≥65	1.09	0.98	1.20	0.11	0.97	0.89	1.05	0.46
Hospital year (per year group)	0.98	0.95	1.00	0.08	0.93	0.91	0.95	<0.01

AW STEMI, anterior wall ST-segment elevation myocardial infarction; NAW STEMI, non-anterior wall ST-segment elevation myocardial infarction; LOS, length of stay; HR, hazard ratio; CI, confidence interval.

*Multivariate Cox proportional hazards regression model was created with an outcome of 30-day readmission including all predictors with p values < 0.1 and in the univariate analysis eliminating backward for p values ≥0.05 (except age group, hospital year, and hospital id number).

Table S5. Independent Predictors of 30-day Mortality After Index PCI with STEMI.

Variables	AW STEMI				NAW STEMI			
	Adjusted HR	95% CI (lower)	95% CI (higher)	P value	Adjusted HR	95% CI (lower)	95% CI (higher)	P value
LOS (Ref: 3 days)								
1-2 days	1.92	1.16	3.16	0.01	0.71	0.48	1.06	0.09
4 days	1.80	1.06	3.04	0.03	1.52	1.00	2.30	0.05
5 days	2.32	1.44	3.73	<0.01	1.76	1.06	2.93	0.03
>5 days	3.45	2.22	5.36	<0.01	2.30	1.45	3.65	<0.01
Female	1.35	1.04	1.75	0.03	n/s			
Diabetes mellitus	1.35	1.02	1.79	0.03	1.34	1.03	1.73	0.03
Dyslipidemia	0.74	0.57	0.96	0.02				
Congestive heart failure	1.86	1.37	2.52	<0.01	2.01	1.45	2.78	<0.01
Peripheral vascular disease	1.62	1.15	2.29	<0.01	n/s			
Renal failure	1.53	1.10	2.14	0.01	1.73	1.28	2.33	<0.01
Anemia	1.59	1.13	2.22	<0.01	1.47	1.06	2.03	0.02
Atrial fibrillation	1.63	1.21	2.19	<0.01	1.50	1.11	2.01	<0.01
Disposition (Ref: home)								
Facility	1.77	1.29	2.42	<0.01	1.80	1.24	2.60	<0.01
AMA/others	3.64	1.26	10.54	0.02	5.64	2.17	14.65	<0.01
Median household income (Ref: 1 st quartile)								
2 nd quartile	0.79	0.56	1.12	0.19	n/s			
3 rd quartile	0.76	0.54	1.06	0.10	n/s			
4 th quartile	0.59	0.39	0.90	0.01	n/s			
Age group, y (Ref: <50)								
50 to 64	1.64	0.94	2.86	0.08	1.74	1.00	3.01	0.05
≥65	4.58	2.66	7.86	<0.01	4.27	2.52	7.24	<0.01
Hospital year (per year group)	1.00	0.87	1.15	0.97	0.93	0.81	1.06	0.28

AW STEMI, anterior wall ST-segment elevation myocardial infarction; NAW STEMI, non-anterior wall ST-segment elevation myocardial infarction; LOS, length of stay; HR, hazard ratio; CI, confidence interval.

*Multivariate Cox proportional hazards regression model was created with an outcome of 30-day readmission including all predictors with p values < 0.1 and in the univariate analysis eliminating backward for p values ≥0.05 (except hospital year and hospital id).

Table S6. Independent Predictors of 30-day Reinfarction After Index PCI with STEMI.

Variables	AW STEMI				NAW STEMI			
	Adjusted HR	95% CI (lower)	95% CI (higher)	P value	Adjusted HR	95% CI (lower)	95% CI (higher)	P value
LOS (Ref: 3 days)								
1-2 days	0.78	0.70	0.86	<0.01	0.84	0.77	0.81	<0.01
4 days	1.26	1.13	1.40	<0.01	1.18	1.07	1.30	<0.01
5 days	1.41	1.25	1.59	<0.01	1.35	1.21	1.51	<0.01
>5 days	1.46	1.32	1.62	<0.01	1.36	1.21	1.50	<0.01
Female	1.22	1.14	1.31	<0.01	1.26	1.18	1.35	<0.01
Smoking	1.12	1.04	1.21	<0.01	n/s			
Congestive heart failure	1.23	1.13	1.33	<0.01	1.36	1.25	1.48	<0.01
Chronic lung disease	1.16	1.05	1.27	<0.01	1.23	1.13	1.33	<0.01
Renal failure	1.38	1.24	1.53	<0.01	1.43	1.30	1.57	<0.01
Atrial fibrillation	1.32	1.19	1.46	<0.01	1.22	1.11	1.33	<0.01
Disposition (Ref: home)								
Facility	1.09	0.98	1.21	0.13	1.24	1.13	1.36	<0.01
AMA/others	2.05	1.53	2.73	<0.01	1.80	1.38	2.35	<0.01
Primary payer (Ref: Medicare)								
Medicaid	1.06	0.90	1.25	0.47	1.01	0.88	1.15	0.93
Private	0.75	0.67	0.85	<0.01	0.81	0.74	0.90	<0.01
Others	0.74	0.64	0.85	<0.01	0.72	0.64	0.81	<0.01
Age group, y (Ref: <50)								
50 to 64	0.97	0.88	1.07	0.59	0.945	0.87	1.04	0.28
≥65	1.15	0.99	1.34	0.06	1.04	0.92	1.17	0.53
Hospital year (per year group)	0.98	0.94	1.02	0.35	0.90	0.87	0.93	<0.01

AW STEMI, anterior wall ST-segment elevation myocardial infarction; NAW STEMI, non-anterior wall ST-segment elevation myocardial infarction; LOS, length of stay; HR, hazard ratio; CI, confidence interval.

*Multivariate Cox proportional hazards regression model was created with an outcome of 30-day readmission including all predictors with p values < 0.1 and in the univariate analysis eliminating backward for p values ≥0.05 (except age group, hospital year and hospital id).

Table S7. Independent Predictors of 30-day Repeat Revascularization After Index PCI with STEMI.

Variables	AW STEMI				NAW STEMI			
	Adjusted HR	95% CI (lower)	95% CI (higher)	P value	Adjusted HR	95% CI (lower)	95% CI (higher)	P value
LOS (Ref: 3 days)								
1-2 days	0.90	0.76	1.01	0.07	0.91	0.82	1.00	0.06
4 days	1.13	0.95	1.37	0.15	1.11	0.98	1.25	0.09
5 days	1.09	0.90	1.34	0.38	1.14	0.97	1.34	0.10
>5 days	1.01	0.85	1.24	0.81	0.96	0.81	1.14	0.62
Smoking	1.20	1.08	1.33	<0.01	0.87	0.80	0.95	<0.01
Diabetes mellitus	1.24	1.09	1.38	<0.01	1.22	1.12	1.33	<0.01
Coagulopathy	0.70	0.51	0.96	0.03	n/s			
Intra-aortic balloon pump	1.24	1.02	1.47	0.03	1.36	1.13	1.64	<0.01
Disposition (Ref: home)								
Facility	0.79	0.64	0.96	0.02	0.77	0.67	0.90	<0.01
AMA/others	2.45	1.67	3.66	<0.01	1.93	1.43	2.60	<0.01
Median household income (Ref: 1 st quartile)								
2 nd quartile	0.93	0.79	1.06	0.21	0.92	0.83	1.02	0.12
3 rd quartile	0.83	0.70	0.95	<0.01	0.89	0.79	0.99	0.03
4 th quartile	0.84	0.71	0.97	0.02	0.83	0.74	0.93	<0.01
Age group, y (Ref: <50)								
50 to 64	1.23	1.05	1.41	<0.01	1.15	1.03	1.28	0.02
≥65	1.63	1.35	1.88	<0.01	1.34	1.19	1.51	<0.01
Hospital year (per year group)	0.90	0.85	0.96	<0.01	0.88	0.83	0.92	<0.01

AW STEMI, anterior wall ST-segment elevation myocardial infarction; NAW STEMI, non-anterior wall ST-segment elevation myocardial infarction; LOS, length of stay; HR, hazard ratio; CI, confidence interval.

*Multivariate Cox proportional hazards regression model was created with an outcome of 30-day readmission including all predictors with p values < 0.1 and in the univariate analysis eliminating backward for p values ≥0.05 (except hospital year and hospital id).

Table S8. Independent Predictors of 30-day Major Adverse Cardiac Event (MACE) After Index PCI with STEMI.

Variables	AW STEMI				NAW STEMI			
	Adjusted HR	95% CI (lower)	95% CI (higher)	P value	Adjusted HR	95% CI (lower)	95% CI (higher)	P value
LOS (Ref: 3 days)								
1-2 days	0.83	0.76	0.91	<0.01	0.86	0.81	0.92	<0.01
4 days	1.25	1.13	1.39	<0.01	1.15	1.06	1.25	<0.01
5 days	1.36	1.22	1.51	<0.01	1.29	1.17	1.43	<0.01
>5 days	1.37	1.24	1.51	<0.01	1.24	1.13	1.36	<0.01
Female	1.19	1.11	1.27	<0.01	1.16	1.10	1.23	<0.01
Hypertension	n/s				1.09	1.03	1.16	<0.01
Diabetes mellitus	1.09	1.02	1.17	0.02	1.15	1.08	1.22	<0.01
Congestive heart failure	1.20	1.11	1.30	<0.01	1.32	1.22	1.42	<0.01
Peripheral vascular disease	1.18	1.04	1.33	<0.01	1.13	1.03	1.24	0.01
Chronic lung disease	1.20	1.09	1.31	<0.01	1.20	1.12	1.29	<0.01
Renal failure	1.39	1.26	1.53	<0.01	1.29	1.18	1.41	<0.01
Anemia	n/s				1.16	1.07	1.26	<0.01
Atrial fibrillation	1.26	1.15	1.38	<0.01	1.17	1.08	1.27	<0.01
Drug abuse	1.23	1.04	1.45	0.01	n/s			
Other neuropathy	n/s				1.28	1.12	1.46	<0.01
Fluid/Electrolyte disorders	n/s				1.12	1.04	1.20	<0.01
Intra-aortic balloon pump	1.12	1.02	1.24	0.02	1.16	1.04	1.30	<0.01
Disposition (Ref: home)								
Facility	1.08	0.97	1.19	0.12	1.14	1.05	1.24	<0.01
AMA/others	2.10	1.63	2.71	<0.01	1.82	1.45	2.27	<0.01
Primary payer (Ref: Medicare)								
Medicaid	1.10	0.96	1.26	0.17	1.02	0.91	1.14	0.72
Private	0.76	0.68	0.85	<0.01	0.81	0.74	0.88	<0.01
Others	0.78	0.68	0.88	<0.01	0.74	0.67	0.81	<0.01
Median household income (Ref: 1 st quartile)								
2 nd quartile	0.97	0.89	1.05	0.43	n/s			
3 rd quartile	0.91	0.83	0.99	0.04	n/s			
4 th quartile	0.90	0.82	1.00	0.04	n/s			
Age group, y (Ref: <50)								
50 to 64	1.00	0.91	1.09	0.95	1.00	0.92	1.07	0.97
≥65	1.18	1.03	1.34	0.01	1.05	0.95	1.16	0.30

Hospital year (per year group)	0.97	0.94	1.01	0.10	0.90	0.87	0.93	<0.01
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AW STEMI, anterior wall ST-segment elevation myocardial infarction; NAW STEMI, non-anterior wall ST-segment elevation myocardial infarction; LOS, length of stay; HR, hazard ratio; CI, confidence interval.

*Multivariate Cox proportional hazards regression model was created with an outcome of 30-day readmission including all predictors with p values < 0.1 and in the univariate analysis eliminating backward for p values ≥ 0.05 (except age group, hospital year and hospital id).