

Modeling of Factors Affecting Hospital Length of Stay in ST-Elevation Patients Using Logistic Regression Models: SEMI CI Study

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Abstract

Background: Ischemic heart disease is a prevalent condition. The length of stay (LOS) for ST-elevation myocardial infarction (STEMI) patients is related to healthcare costs and resources. This study aims to determine the underlying risk factors for longer LOS in STEMI patients at Chamran Hospital, Isfahan, Iran.

Materials and Methods: In this study, which is part of the STEMI cohort study (SEMI-CI) in Isfahan, Iran, patients with STEMI admitted to Chamran Hospital from March 2015 to March 2016 were identified. The association between risk factors and LOS was evaluated by trained nurses using medical archives. Logistic regression analysis identified independent predictors of LOS. Data were analyzed using SPSS Statistics 22 (IBM, Inc., Armonk, NY, USA), and the significance level was set at an alpha value of <0.05.

Results: Of 867 STEMI patients, 760 had complete information. The median LOS for surviving patients was three days. Patients with longer hospitalization times were predominantly older, more likely to be female, had lower left ventricular ejection fraction (LVEF) and hemoglobin, a history of cardiovascular diseases (CVD), hypertension, and heart failure, and had previously used beta-blockers, statins, aspirin, angiotensin-converting enzyme inhibitors, and angiotensin receptor blockers. The results of logistic regression models showed that higher low-density lipoprotein cholesterol (LDL-C) ($P = 0.032$), lower hemoglobin ($P = 0.004$), and lower LVEF ($P = 0.019$) were three risk factors for increased length of hospitalization.

Conclusion: Identifying and controlling the factors affecting the LOS of STEMI patients (such as LDL-C, hemoglobin levels, and LVEF) can help reduce LOS, decrease the overuse of medical resources, and improve patient recovery.

Keywords: Length of stay, risk factors, ST-elevation myocardial infarction

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Submitted: 22-Jan-2025; **Revised:** 15-Aug-2025; **Accepted:** 16-Aug-2025; **Published:** 29-May-2026

INTRODUCTION

Myocardial infarction (MI) is one of the leading causes of mortality worldwide.^[1] MI has a high prevalence among both sexes in Iran and globally.^[2,3] One of the most severe

manifestations of acute coronary syndrome (ACS) is ST-elevation myocardial infarction (STEMI).^[4] In the United States, approximately 500,000 new cases and 200,000 recurrent cases

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How to cite this article: Agharazi M, Shirvani E, Jamalian M, Roohafza H, Tavassoli Naini P, Karimian A, *et al.* Modeling of factors affecting hospital length of stay in ST-elevation patients using logistic regression models: SEMI CI study. *Adv Biomed Res* 2026;15:27.

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DOI:
10.4103/abr.abr_50_25

of MI are reported annually.^[3] Given the prevalence of MI and the associated hospital-related costs, hospitalization for MI can be very expensive.^[5] Although guidelines suggest that it is safe to discharge low-risk MI patients within 72 h of hospitalization, the length of stay (LOS) for MI patients is often longer and varies across different countries.^[6] Therefore, reducing LOS in these patients could be highly cost-effective for the healthcare system and improve the management of hospital beds and manpower.^[2] Improved management of MI has significantly reduced LOS for acute MI patients in recent decades.^[7] However, there are concerns that financial pressures and shortened hospital stays may increase the risk of adverse outcomes for STEMI patients.^[8] Nevertheless, because of MI complications, hospital-related care for STEMI patients is important, and a longer LOS can provide an opportunity to monitor patients better.^[9] Understanding and controlling the factors influencing LOS in these patients can help optimize costs, healthcare resources, hospital management, manpower, and patient monitoring. In other words, identifying these factors can promote the earliest and safest discharge of these patients. To our knowledge, few studies have examined this topic in Iran or the Middle East, highlighting the need for further research in this region. In this study, we sought to determine the factors that affect LOS in patients diagnosed with STEMI at Chamran Hospital, Isfahan.

MATERIALS AND METHODS

This study is part of the STEMI Cohort Study (SEMI-CI), involving 867 STEMI patients in Isfahan, Iran.^[10]

Inclusion criteria: Patients who presented to the hospital emergency room with the manifestations of ACS and were diagnosed with STEMI and hospitalized at Chamran Hospital, Isfahan, between March 2015 and March 2016, with complete medical records. Patients presenting with a new left bundle branch block accompanied by typical chest pain and elevated cardiac enzymes were also included as acute myocardial infarction (AMI) cases.

Exclusion criteria

Patients without a confirmed diagnosis of AMI/STEMI or with incomplete medical records. For incomplete records, the research team contacted patients or their families using available contact numbers to obtain consent for completing the information. Patients who declined or could not be reached were excluded.

Sample size and sampling method

The sample size included all individuals with complete records during the specified period (March 2015 to March 2016). The data collection tool was a checklist.

Methodology

Initially, all participants (or their immediate family members in cases of unconsciousness) provided informed consent. All participant data were entered into forms specifically designed for this purpose. Each participant was assigned a unique number, and their national ID, full name, hospital file number,

home address, two contact numbers, date of birth, marital status, and type of insurance were recorded. Trained nurses, who underwent 10 sessions of 1.5-h training and monthly refresher courses, completed the checklists.

This study had four phases of data collection:

- Phase 1: Pre-hospital phase, including pre-hospital diagnosis, symptom onset time and duration, admission process, transfer route to the emergency room, referral location (clinic, outpatient clinic, general hospital), medication use, and pre-admission cardioversion.
- Phase 2: Hospital phase, including initial electrocardiogram diagnosis for AMI timing, AMI location, blood pressure, heart rate at admission, patient history (including hypertension, diabetes, hyperlipidemia, atrial fibrillation, smoking, stroke, previous ischemic heart disease), psychological assessment, angiography and angioplasty data, revascularization treatment, ejection fraction (EF) before discharge, laboratory data (hemoglobin, creatinine, low-density lipoprotein cholesterol (LDL-C), rhythm, and hemodynamic complications. Case report forms describe interventions like percutaneous coronary intervention (PCI), coronary artery bypass grafting, intra-aortic balloon pump, and pacemaker use.
- Phase 3: Discharge phase, including final diagnosis, prescribed medications, referrals to other hospitals, and atrial fibrillation status on the last day of hospitalization.
- Phase 4: Follow-up phase.

After this, the researchers visited the cardiac center and collected data through checklists. The collected data included personal information (name, national ID, file number, patient ID, admission and discharge dates, contact numbers and address), and medical data (LOS, systolic and diastolic blood pressure, age, body mass index (BMI), diabetes, hyperlipidemia, hemoglobin, creatinine, heart rate, EF, heart failure status, LDL-C, hypercholesterolemia, type of treatment, medical history, and hospital complications).

Statistical analysis

All data were normally distributed. Quantitative variables were described using means and standard deviations. The quantitative variables included age, BMI, LVEF, hemoglobin, LDL, total cholesterol, systolic blood pressure, and creatinine. Independent (two-sample) Student's t-tests were applied for continuous variables. The Chi-square test was used for categorical (nominal and dichotomous) variables. Logistic regression was performed to identify independent predictors of longer hospital stays (≥ 3 days, the median LOS of the patients in our study). All baseline variables were considered, and the probability value for covariates to enter the model was set at 0.05. Results are presented as odds ratios (OR) with the associated 95% confidence intervals (CI) for logistic regression. The level of statistical significance was set at an alpha value of <0.05 . All analyses were conducted using SPSS Statistics 22 (IBM, Inc., Armonk, NY, USA).

RESULTS

Baseline characteristics are shown in Table 1. Of 867 patients, 760 met the inclusion criteria and entered this study. The mean age of the patients was 61.37 ± 13.11 , and most patients were male. During the hospital stay, 631 (93.3%) patients survived until discharge. Among surviving patients, the median LOS was three days (Q1: 3; Q3: 4). A histogram of the LOS across the study population is presented in Figure 1. Patients with prolonged hospital stays (≥ 4 days) were significantly older ($P = 0.004$), more likely to be female ($P = 0.029$), and had lower LVEF ($P < 0.001$) and hemoglobin levels ($P < 0.001$). A history of hypertension ($P = 0.008$), cardiovascular diseases (CVD) ($P = 0.030$), and heart failure ($P = 0.052$) was associated with longer hospitalization (it should be

noted that the P value for heart failure, while not statistically significant, was borderline, suggesting its potential relevance). Patients who had previously used beta-blockers ($P = 0.018$), statins ($P = 0.022$), aspirin ($P = 0.005$), angiotensin-converting enzyme (ACE) inhibitors ($P = 0.001$), and angiotensin receptor blockers (ARBs) ($P = 0.03$) experienced longer hospital stays [Table 1]. Table 2 presents the logistic regression model for predicting longer hospital stays (≥ 4 days). Results of the logistic regression model identified LDL-C ($P = 0.032$, OR = 1.011), hemoglobin ($P = 0.004$, OR = 0.680), and LVEF ($P = 0.019$, OR = 0.949) as independent risk factors for extended hospitalization. The ORs indicate that higher LDL-C and lower hemoglobin and LVEF are associated with longer LOS.

Table 1: Baseline and in-hospital clinical characteristics

Variables	LOS ≤ 3 days ($n=478$, 62.9%)	LOS ≥ 4 days ($n=282$, 37.1%)	P
Demographic			
Age (years), mean $\pm$ SD	59.73 $\pm$ 12.74	62.50 $\pm$ 13.11	0.004
Sex (male), n (%)	407 (85.1)	222 (78.7)	0.029
History, n (%)			
Smoking	195 (40.7)	101 (35.8)	0.076
Hypertension	139 (29.08)	115 (40.8)	0.008
Diabetes	141 (29.5)	77 (27.3)	0.352
Chronic heart failure	49 (10.3)	44 (15.6)	0.052
History of CVD	132 (27.6)	96 (34.0)	0.030
Clinical factors (mean $\pm$ SD)			
BMI (kg/m ²)	26.35 $\pm$ 4.19	26.27 $\pm$ 4.23	0.799
LVEF (%)	38.76 $\pm$ 11.99	34.87 $\pm$ 10.74	<0.001
Hb (mg/dl)	14.08 $\pm$ 2.04	13.15 $\pm$ 2.46	<0.001
Creatinine (mg/dl)	1.20 $\pm$ 0.35	1.25 $\pm$ 0.48	0.117
LDL-C (mg/dl)	112.68 $\pm$ 38.12	106.45 $\pm$ 44.81	0.140
Total cholesterol (mg/dl)	180.47 $\pm$ 46.69	173.58 $\pm$ 54.58	0.173
SBP (mmHg)	126.92 $\pm$ 28.29	124.84 $\pm$ 24.97	0.293
Type of treatment, n (%)			
PPCI	277 (57.9)	156 (55.3)	0.519
Thrombolysis	191 (39.9)	119 (42.2)	
Details of disease, n (%)			
Timi flow in culprit vessel before PCI (≥ 2)	165 (34.5)	94 (33.3)	0.663
Timi flow in culprit vessel after PCI (≥ 2)	356 (96.2)	218 (96.5)	0.999
Type of MI, n (%)			
Anterior	230 (54.9)	151 (58.8)	0.326
Others	189 (45.1)	106 (41.2)	
Number of epicardial territories with stenosis $>50\%$, n (%)			
1	195 (48.5)	100 (40.3)	0.083
2	126 (31.3)	83 (33.5)	
3	81 (20.1)	65 (26.2)	
Previous treatment, n (%)			
Beta-blockers	77 (18.4)	67 (26.1)	0.018
Statins	94 (22.4)	78 (30.4)	0.022
Aspirin	127 (30.3)	105 (40.9)	0.005
ACE inhibitors	12 (2.9)	22 (8.6)	0.001
ARBs, n (%)	59 (8.7)	58 (22.6)	0.003

LOS=Length of stay, CVD=Cardiovascular disease, BMI=Body mass index, LVEF=Left ventricular ejection fraction, Hb=Hemoglobin, LDL-C=Low-density lipoprotein cholesterol, SBP=Systolic blood pressure, PPCI=Primary percutaneous coronary intervention, TIMI=Thrombolysis in myocardial infarction, MI=Myocardial infarction, ACE=Angiotensin-converting enzyme, ARBs=Angiotensin receptor blockers, SD=Standard deviation

DISCUSSION

In this study, to our knowledge, a comprehensive model has been developed to evaluate the risk factors that result in longer LOS for STEMI patients. This model can be used to assist hospitals and clinicians in managing these patients. As evaluated by logistic regression models, three variables at the time of arrival were found to predict the LOS for STEMI patients (including LDL-C, hemoglobin, and lower LVEF).

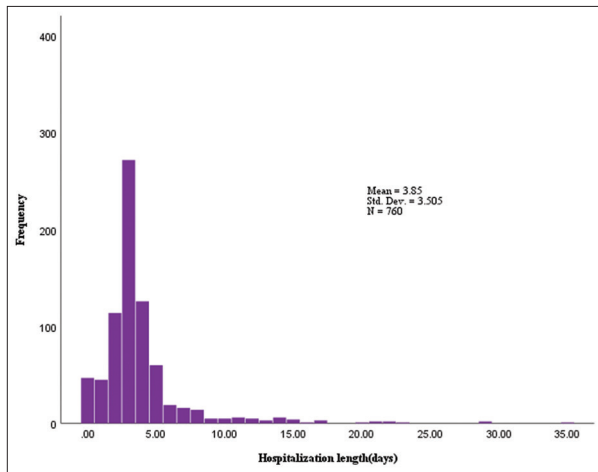


Figure 1: Histogram of the length of hospital stays in ST-elevation myocardial infarction patients

The focus on STEMI patients, as well as different hospital care practices and treatments, may explain the differences between these studies. However, since longer LOS incurs substantial costs for both hospitals and patients, these cases in different regions of the world need further investigation.

The results showed that higher LDL-C levels can lead to a longer LOS in STEMI patients, whereas in a prior study,^[9] 65.3% of individuals with hyperlipidemia had a LOS of less than 3 days. Elevated LDL-C is associated with worse long-term outcomes after MI, such as higher rates of reinfarction or slower recovery.^[11] Higher LDL levels can cause endothelial dysfunction, which impairs the ability of blood vessels to dilate, thus reducing blood flow to damaged tissue.^[12]

In our study, lower hemoglobin levels were identified as a risk factor for longer LOS in STEMI patients. This is in line with Jhand *et al.* study, in which among patients with MI anemia was associated with longer LOS.^[13] It can be due to the comorbidities that anemia may cause among these patients, such as reduced myocardial salvage and impaired left ventricular function.^[14]

Furthermore, in this study, lower LVEF was associated with longer LOS in STEMI patients, corroborating the findings of other studies.^[2,15-18] This can be due to the complications that lower LVEF causes in ischemic heart disease patients, as it

Table 2: Logistic regression model for predicting hospitalization lengths ≥ 4 days

Variables	B	SE	OR	95% CI for OR		P
				Lower	Upper	
Age (years)	-0.022	0.021	0.978	0.939	1.019	0.280
Sex (male)	0.262	0.777	1.300	0.283	5.963	0.736
BMI (kg/m ²)	-0.093	0.059	0.911	0.812	1.022	0.112
Current smoker	-0.697	0.467	0.498	0.199	1.244	0.136
Previous CVD	-0.322	0.427	0.724	0.314	1.672	0.450
Chronic heart failure	-0.534	0.713	0.586	0.145	2.372	0.454
Hypertension	0.578	0.666	1.783	0.484	6.571	0.385
Diabetes	-0.363	0.524	0.696	0.249	1.944	0.489
LDL-C (mg/dl)	0.011	0.005	1.011	1.001	1.021	0.032
Creatinine (mg/dl)	0.874	0.872	2.396	0.434	13.237	0.316
Hemoglobin (mg/dl)	-0.386	0.134	0.680	0.523	0.883	0.004
LVEF(%)	-0.052	0.022	0.949	0.908	0.991	0.019
Type of treatment	0.023	0.255	1.023	0.621	1.685	0.929
Timi flow in culprit vessel before PCI (≥ 2)	-0.334	0.434	0.716	0.306	1.677	0.442
Number of epicardial territories with stenosis $>50\%$						0.883
1	0.195	0.629	1.215	0.354	4.168	0.757
2	0.313	0.637	1.368	0.393	4.763	0.623
Aspirin usage	0.888	0.482	2.429	0.944	6.251	0.066
Beta-blockers usage	0.761	0.590	2.141	0.674	6.804	0.197
ACE inhibitors usage	0.467	0.894	1.595	0.277	9.203	0.601
ARBs usage	-0.631	0.663	0.532	0.145	1.949	0.341
Statins usage	-0.301	0.571	0.740	0.241	2.268	0.598

BMI=Body mass index, CVD=Cardiovascular disease, LDL-C=low-density lipoprotein cholesterol, LVEF=Left ventricular ejection fraction, TIMI=Thrombolysis in myocardial infarction, ACE=Angiotensin-converting enzyme, ARBs=Angiotensin receptor blockers, B=Estimated logit coefficient, SE=Standard error, OR=Odds ratio, CI=Confidence interval

increases the risk of adverse outcomes and functional disability in these patients.^[19,20]

Additionally, patients with longer LOS in this study were generally older, female, had lower LVEF, and had more comorbidities, such as hypertension, a history of CVD, and heart failure. Patients who had previously used beta-blockers, statins, aspirin, ACE inhibitors, and ARBs also had longer hospital stays.

In some previous studies, the LOS for STEMI patients was longer in females compared to males,^[21-24] and also many studies have observed a relationship between older age and longer LOS.^[2,9,15,18,21-23] This may be attributed to the older age of women who experience MI compared to men, and the fact that older individuals are more likely to have multiple comorbidities.^[25] Additionally, calcification, decreased endothelial function, and a history of previous cardiac diseases are more common in older individuals.^[26] Furthermore, females are at higher risk for vascular complications, bleeding, and developing thrombosis after PCI.^[27,28]

The present study shares a good number of similarities with Jang *et al.* study, as in both articles older age, female gender, more previous CVD, congestive heart failure, anemia, and hypertension were associated with longer LOS.^[29] Hypertension can cause endothelial damage, arrhythmias, and heart failure,^[15,30,31] affecting recovery time.

In contrast to our results, some studies have found smoking to be associated with a longer LOS,^[21,16,23] while others found that patients with longer LOS were less likely to be smokers.^[15,29] Although smoking is related to atherosclerosis and platelet aggregation, a controversial phenomenon known as the “smoker’s paradox” suggests that smoking is associated with fewer comorbidities after MI, possibly due to the younger age of smokers.^[32]

Contrary to some prior studies,^[2,15] this study found no association between longer LOS and higher BMI. Although there is a relationship between obesity and atherosclerosis, inflammatory factors, and oxidative stress which can affect the recovery process of the patients,^[33] there is also an obesity paradox among MI patients which suggests that overweight patients have better prognoses than those with normal body weight.^[34]

While the prior use of cardiac medications can be beneficial in preventing heart diseases, in some circumstances, these medications can affect the LOS of MI patients, as some require dose adjustments, interact with new medications, and also have potential side effects.^[35]

There are several limitations to this study. First, our results were derived from a single tertiary referral hospital center caring for STEMI patients, and as with all single-source studies, the findings cannot be generalized to other regions of the country or world. Additionally, some unmeasured factors and laboratory data during the index admission may be associated with the

LOS of these patients. Therefore, we suggest that this study be replicated in other regions with large sample sizes, especially in other provinces of Iran. It is also recommended to include data on STEMI processes of care, additional laboratory data, and other factors that may be associated with LOS (such as discharge protocols, hospital healthcare quality, medications during hospitalization, angiographic failure, and peripheral vascular complications) and evaluate some factors more specifically (including MI locations) to develop a predictive model for LOS. This could be a novel idea for future research.

CONCLUSION

Our data and analysis showed that higher LDL-C levels, lower hemoglobin levels, and lower LVEF were associated with a longer LOS in STEMI patients. LOS has attracted significant attention from health policymakers due to its impact on the proper use of resources, medical facilities, and healthcare costs. Therefore, it is important to educate clinicians to consider and manage patients with these identified risk factors to reduce the overuse of medical resources and improve patient outcomes. Additionally, greater emphasis on treating these underlying factors in high-risk cardiac patients is recommended to reduce the likelihood of these adverse events.

Acknowledgment

We used ChatGPT 3.5 with the following prompt “Is this paragraph grammatically correct?” to improve the English language of the article.

Ethics approval and consent to participate

Ethical approval was obtained from the Research Ethics Committee of Isfahan University of Medical Sciences (Approval ID: IR.ARI.MUI.REC.1403.219).

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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