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Original Article

Long-Term Hospital Readmission after ST-Elevation Myocardial Infarction: A 3-Year Follow-up from the SEMI-CI Study

Parsa Tavassoli Naini, MD[1], Marjan Jamalian, MSc[2*], Ali Riahi, MD[1], Hamid Reza Roohafza, MD[1], Azam Soleimani, MD[3], Mohammadreza Shafiei, PhD[4], Mohammad Agharazi, MD[5], Masoumeh Sadeghi, MD[2]

[1]*Isfahan Cardiovascular Research Center, Cardiovascular Research Institute, School of Medicine, Isfahan University of Medical Sciences, Isfahan, Iran.*
[2]*Cardiac Rehabilitation Research Center, Cardiovascular Research Institute, Isfahan University of Medical Sciences, Isfahan, Iran.*
[3]*Heart Failure Research Center, Cardiovascular Research Institute, Isfahan University of Medical Sciences, Isfahan, Iran.*
[4]*Chamran Cardiovascular and Medical Research Hospital, Isfahan University of Medical Sciences, Isfahan, Iran.*
[5]*Interventional Cardiology Research Center, Cardiovascular Research Institute, School of Medicine, Isfahan University of Medical Sciences, Isfahan, Iran.*

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Abstract

Background: *This study aimed to investigate readmission risk factors after ST-elevation myocardial infarction (STEMI) during a 3-year follow-up.*

Methods: *This study is a secondary analysis of the STEMI Cohort Study (SEMI-CI) in Isfahan, Iran, with 867 patients. A trained nurse gathered the demographic, medical history, laboratory, and clinical data at discharge. Then the patients were followed up annually for 3 years by telephone and invitation for in-person visits with a cardiologist concerning readmission status. Cardiovascular readmission was defined as MI, unstable angina, stent thrombosis, stroke, and heart failure. Adjusted and unadjusted binary logistic regression analyses were applied.*

Results: *Of 773 patients with complete information, 234 patients (30.27%) experienced 3-year readmission. The mean age of the patients was 60.92±12.77 years, and 705 patients (81.3%) were males. The unadjusted results showed that smokers were 21% more likely to be readmitted than nonsmokers (OR, 1.21; P=0.015). Readmitted patients had a 26% lower shock index (OR, 0.26; P=0.047), and ejection fraction had a conservative effect (OR, 0.97; P<0.05). The creatinine level was 68% higher in patients with readmission. An adjusted model based on age and sex showed that the creatinine level (OR, 1.73), the shock index (OR, 0.26), heart failure (OR, 1.78), and ejection fraction (OR, 0.97) were significantly different between the 2 groups.*

Conclusion: *Patients at risk of readmission should be identified and carefully visited by specialists to help improve timely treatment and reduce readmissions. Therefore, it is recommended to pay special attention to factors affecting readmission in the routine visits of STEMI patients.*

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Corresponding Author:** ***Marjan Jamalian, *Cardiac Rehabilitation Research Center, Cardiovascular Research Institute, Isfahan University of Medical Sciences, Shahid Rahmani Alley, After Shahrestan Bridge, Mushtaq 3rd Street, Isfahan, Iran. 81583-88994. Tel:+98 31 36115210. Fax:+98 31 36115209. E-mail: marjanjamalian@gmail.com.*

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Keywords: *ST-elevation myocardial infarction; Hospital readmission; Risk factors*

Introduction

ST-elevation myocardial infarction (STEMI) is one of the most severe coronary artery diseases resulting in increased morbidity and mortality and causing a decline in the social, physical, and psychological functionality of affected patients.[1, 2] In Iran, the 12-year trend of in-hospital mortality and hospital length of stay for STEMI has decreased, and primary percutaneous coronary intervention (PCI) has replaced thrombolysis in the management of patients; nonetheless, the outcome of this group of patients is different from that in other countries.[3] Risk factors play an important role in the early onset of the disease at a younger age. Therefore, identifying risk factors and their management over time can help control the disease.[4] STEMI-surviving patients are at serious risk for recurrent coronary artery disease after discharge because of the chronic process of the blockage of a major artery.[5] The readmission rate is an important indicator in evaluating the efficacy of healthcare systems and the preventive and sanitary steps to avoid such events. Recent studies have reported that approximately 20% of patients have unplanned readmission within 30 days of discharge, with an estimated direct cost of $US 1 billion to healthcare systems annually.[6]

Readmission impacts hospitals and patients and is associated with unfavorable patient outcomes and high financial costs. Predictive models to identify patients at the highest risk for readmission after acute MI could help provide ideal hospital care post-discharge. Thus, since 2013, the Hospital Readmission Reduction Program (HRRP) has been carried out by the United States, whereby penalties are applied for higher-than-expected 30-day readmission rates after MI to improve the quality of care and reduce expenses.[7]

Nguyen et al[8] reported readmission predictors to be renal function, elevated brain natriuretic peptide, age, diabetes mellitus, sex, timely PCI, and low systolic blood pressure. Older age and a history of diabetes mellitus or heart failure have also been reported as readmission predictors.[9] The results of other studies, albeit somewhat similar to the abovementioned risk factors, certainly had some differences, prompting further evaluations and examinations of this topic.

Prior studies using data to predict risk factors have achieved valuable insights in developed countries, such as the United States.[10] Nonetheless, the information needs further investigation to be generalizable to other parts of the world and countries such as Iran. Moreover, most studies had only a 30-day follow-up period from the initial acute MI, so there is a lack of a more profound understanding of how these risk factors change with time beyond the 30 days.[11] Besides the high readmission rates after MI, the aforementioned needs highlight the importance of further research to learn more about readmission patterns.

To the best of our knowledge, there are few long-term follow-up studies of STEMI patients, with follow-ups usually within 30 days or 90 days of hospital admission. Additionally, no studies have hitherto reported the mortality of these patients in Asian regions. Accordingly, the present study aimed to determine the underlying 3-year causes of readmission to devise strategies to reduce the burden of recurrent STEMI.

Methods

This cohort study is a secondary analysis of the STEMI Cohort Study (SEMI-CI) in Isfahan, Iran. This study was conducted on 867 patients with STEMI referred to cardiology referral centers affiliated with Isfahan University of Medical Sciences from March 2015 through March 2016.[12] A trained nurse gathered the study population's demographic characteristics (age, sex, current smoking, and body mass index [BMI]), medical history (diabetes mellitus, hypertension, and hypercholesterolemia), laboratory data (creatinine and hemoglobin) clinical data (systolic and diastolic blood pressures, ejection fraction, heart rate, and heart failure) and the number of epicardial territories.

This study measured the patients' upright height and weight using a standard meter and scale. BMI was then calculated as weight (in kilograms) divided by squared height (in meters). Diabetes mellitus was defined as fasting plasma glucose levels ≥126 mg/dL or postprandial blood glucose levels >200 mg/dL on multiple measurements. Hypercholesterolemia was considered total cholesterol levels >200 mg/dL or the use of lipid-lowering medication. High systolic blood pressure was reported as levels >140 mm Hg, and high diastolic blood pressure was reported as levels >90 mm Hg. Heart rate is the number of heartbeats per minute, normally between 60 and 100 beats per minute for adults. In this study, heart rate was divided into ≤60 bmp, 61–76 bmp, and ≥76 bmp. Ejection fraction is the percentage of blood pumped out of the ventricles during each contraction, and EF <50% is abnormal. Ejection fraction and heart rate were measured at hospital discharge. Cardiovascular readmission was defined as hospitalization due to MI, unstable angina, stent thrombosis, stroke, or heart failure.

The inclusion criteria included hemodynamically stable patients aged >18 years with the manifestations of STEMI or new-onset left bundle branch blocks. The exclusion criteria included acute MI during a balloon angioplasty procedure, the simultaneous presence of other major medical conditions (eg, chronic kidney, liver, thyroid, and brain diseases), and major psychiatric disorders. Patients who died during these periods were excluded from the study.

In this study, the mean arterial pressure (MAP), the shock index (SI), the modified shock index (MSI), and the age shock index (age SI) were calculated.

MAP measurement explains the average blood pressure in a patient's arteries during 1 cardiac cycle and is considered a better indicator of perfusion to body organs than systolic blood pressure. True MAP can only be determined with an invasive central line; however, it can also be calculated using another equation using systolic and diastolic blood pressures. MAP was calculated using the following formula[13]:

MAP = (systolic blood pressure + 2 (diastolic blood pressure)/3

SI is a bedside ratio defined as heart rate divided by systolic blood pressure and recognized as an indicator of the severity of hypovolemic shock and hemodynamic status. It is used to assess prognosis in different settings, including STEMI.18 MSI, defined as heart rate divided by MAP, is reported in small studies to predict mortality better than do heart rate, blood pressure, and SI in medical and trauma emergency patients.[14] Age SI, defined as age in years multiplied by SI, is superior to SI and MSI for predicting long-term prognosis in acute MI.[15]

After discharge, a trained nurse gathered the patients' readmission information from the hospital annually and then interviewed them to fill out questionnaires. MI, unstable angina, stent thrombosis, stroke, and heart failure were the causes of readmission diagnosed by a cardiologist panel. The patients were followed up annually for 3 years by telephone and invitation for in-person visits with a cardiologist to check readmission status.

The obtained data were entered into the Statistical Package for Social Sciences (SPSS; version 20.0, SPSS Inc, Chicago, IL, USA). The descriptive data were presented in means, standard deviations (SDs), absolute numbers, and percentages.

Our response variable was the readmission status of STEMI patients (with and without readmission) in 3 years from 2016 through 2019. The independent variables assessed were demographic variables, including age, sex, BMI, diabetes, and current smoking status. The indices investigated included SI, age SI, MAP, and MSI. The clinical variables analyzed were heart failure, heart rate, ejection fraction, systolic and diastolic blood pressures, creatinine, hemoglobin, hypertension, and hypocholesteremia.

The patients were divided into 2 groups: patients with readmission and those without readmission. The χ^2 test was used to compare the frequencies between the groups, and the t test was employed to compare continuous variables. Univariate binary logistic regression analysis was applied to find factors affecting readmitted patients. A univariate logistic regression model was created with and without age and sex adjustments. Odds ratios (ORs) were reported with the corresponding 95% confidence intervals (95% CIs). A P value <0.05 was considered statistically significant.

Results

Totally, 867 patients with MI were diagnosed during the study period. Complete information about readmission was available for 733. The mean (SD) age of the patients was 60.92 (12.77) years, ranging from 18 to 94 years, and 705 patients (81.3%) were males. Readmission was reported in 234 patients (30.27%). Significant factors affecting readmission among demographic, physiological, and laboratory parameters (Table 1) included smoking (P=0015), SI (P=0.026), ejection fraction (P<0.001), and the creatinine level (P=0.0028). Heart failure was borderline significant (P=0.051). Further, 47.3% of the readmitted patients were smokers. Higher readmission risks were associated with lower ejection fractions, higher creatinine levels, and lower SIs.

The unadjusted model showed that smokers were 21% more likely to be readmitted than nonsmokers (OR, 1.21; P=0.015). A higher SI decreased the probability of readmission by 26% (OR, 0.259; P=0.047). A higher EF decreased the probability of readmission by about 97%. Additionally, 68% of the patients with readmission had higher creatinine levels than those without readmission. The adjusted model showed that the creatinine level (P=0.009), SI (P=0.051), heart failure (P=0.047), and ejection fraction (P<0.001) were still significant variables affecting readmission (Table 2). The study population was classified into 3 treatment groups: primary PCI, thrombolysis, and medical treatment. Primary PCI was performed on 352 patients, 111 of whom (47.4%) were readmitted. Thrombolysis was performed on 364 patients, 108 of whom (46.2%) were readmitted. Medical treatment was done for 57 patients, 15 of whom (6.4%) were readmitted. No statistically significant differences in the risk factors were observed between the 3 treatment groups.

Table 1. Demographic data and clinical conditions associated with readmission in patients with STEMI in a 3-year follow-up*

Variable	Total	Readmission (n=234)	Non-Readmission (n=539)	P
Demographics				
Age (y)	60.92±12.77	59.98±12.50	60.00±12.46	0.981
Sex (male)	642 (83.1)	195 (83.3)	447 (82.9)	0.891
BMI	26.30±4.05	26.18±4.24	26.51±3.96	0.333
Current smoking	316 (40.9)	111 (47.4)	205 (38.0)	0.015**
Medical history				
Diabetes (mg/dL)	220 (28.5)	74 (31.6)	146 (27.1)	0.199
Hypertension (mm Hg)	266 (34.4)	80 (34.2)	186 (34.5)	0.931
Hypocholesteremia (mg/dL)	236 (30.5)	78 (33.30)	158 (29.3)	0.265
Laboratory data				
Cr (mg/dL)	1.23±0.45	1.26±0.59	1.16±0.29	0.028**
Hb (g/dL)	14.31±1.87	14.33±1.83	14.45±1.77	0.405
Clinical Measures				
SI	0.57±0.15	0.55±0.13	0.58±0.17	0.026**
Age**SI	33.54±11.27	32.44±10.27	34.02±11.66	0.145
MSI	0.74±0.16	0.72±0.16	0.75±0.16	0.085
MAP	95.04±16.09	96.27±15.64	96.57±15.28	0.841
HF	55 (7.1)	23 (9.9)	32 (5.9)	0.051
HR (bmp)				0.297
≤60	93 (18.1)	33 (21.3)	60 (16.7)	
61-76	255 (49.5)	78 (50.3)	177 (49.2)	
≥76	167 (32.4)	44 (28.4)	123 (34.2)	
EF	37.80±11.74	35.89±11.49	39.35±11.59	<0.001**
SBP (mmHg)	126.91±27.25	128.05±24.62	129.86±26.84	0.379
DBP (mmHg)	79.38±14.20	81.21±14.28	80.24±13.28	0.458
Number of Epicardial Territories				0.245
≤1	310 (45.9)	105 (49.3)	205 (44.4)	
≥2	365 (54.1)	108 (50.7)	257 (55.6)	

*Data are presented as mean±SD or n (%).
**Statistically significant for variables P<0.05.
STEMI, ST-elevation myocardial infarction; BMI, Body mass index; Cr, Creatinine; Hb, Hemoglobin; SI, Shock index; Age**SI, Age**Shock index; MSI, Modified shock index; MAP, Mean arterial pressure; HF, Heart failure; HR, Heart rate; EF, Ejection fraction; SBP, Systolic blood pressure; DBP, Diastolic blood pressure

Table 2. Comparison of the unadjusted univariate logistic regression model and the age and sex-adjusted model to identify risk factors in STEMI patients in a 3-year follow-up*

	Unadjusted Model					Adjusted Model				
	Estimate	SE	OR	CI (95%)	P	Estimate	SE	OR	CI (95%)	P
Demographic Characteristics										
Age (y)	0.000	0.01	1.00	(0.99-1.01)	0.981	-	-	-	-	-
Sex	0.01	0.11	1.01	(0.83-1.25)	0.891	-	-	-	-	-
BMI (kg/m^2)	-0.02	0.02	0.98	(0.94-1.02)	0.333	-0.03	0.02	0.97	(0.93-1.02)	0.245
Smoking	0.19	0.08	1.21	(1.04-1.42)	0.015**	-0.02	0.20	0.98	(0.66-1.45)	0.919
History										
Diabetes (mg/dL)	0.05	0.04	1.06	(0.97-1.15)	0.199	0.06	0.04	1.06	(0.97-1.16)	0.181
Hypertension (mm Hg)	-0.01	0.08	0.99	(0.84-1.17)	0.931	-0.004	0.09	0.99	(0.84-1.18)	0.961
Hypocholesteremia (mg/dL)	0.09	0.08	1.10	(0.93-1.29)	0.265	0.10	0.08	1.10	(0.93-1.30)	0.255
Laboratory										
Cr (mg/dL)	0.52	0.20	1.68	(1.13-2.51)	0.011**	0.55	0.21	1.73	(1.15-2.62)	0.009**
Hb (g/dL)	-0.04	0.04	0.96	(0.88-1.05)	0.398	-0.06	0.05	0.95	(0.86-1.04)	0.262
Clinical Measures										
SI	-1.35	0.68	0.26	(0.07-0.98)	0.047*	-1.33	0.68	0.26	(0.07-1.00)	0.051**
Age**SI	-0.01	0.01	0.99	(0.97-1.01)	0.146	-0.02	0.01	0.98	(0.96-1.00)	0.072
MSI	-1.355	0.79	0.26	(0.05-1.21)	0.086	-1.29	0.80	0.27	(0.06-1.30)	0.104
MAP	-0.001	0.01	1.00	(0.99-1.01)	0.841	-0.001	0.01	1.00	(0.99-1.01)	0.873
HF	0.55	0.28	1.73	(0.99-3.04)	0.053**	0.58	0.29	1.78	(1.007-3.139)	0.047**
HR (bmp)***										
≤60	0.43	0.28	1.54	(0.89-2.66)	0.123	0.42	0.28	1.53	(0.88-2.66)	0.135
61-76	0.21	0.22	1.23	(0.80-1.90)	0.348	0.20	0.28	1.22	(0.78-1.91)	0.375
EF	-0.03	0.01	0.97	(0.96-0.99)	<0.001**	-0.03	0.01	0.97	(0.96-0.99)	<0.001**
SBP (mmHg)	-0.003	0	1.00	(0.99-1.00)	0.379	-0.003	0.01	1.00	(0.99-1.00)	0.380
DBP (mmHg)	0.01	0.01	1.01	(0.99-1.02)	0.457	0.01	0.01	1.01	(0.99-1.02)	0.463
Number of Epicardial Territories (≤1 ratio≥2)	-0.20	0.17	0.82	(0.59-1.14)	0.233	-0.06	0.11	0.94	(0.77-1.15)	0.571

*Data are presented as mean±SD or n (%).
**Statistically significant for variables P<0.05.
***References, HR≥76
STEMI, ST-elevation myocardial infarction; BMI, Body mass index; Cr, Creatinine; Hb, Hemoglobin; SI, Shock index; Age**SI, Age**Shock index; MSI, Modified shock index; MAP, Mean arterial pressure; HF, heart failure; HR, Heart rate; EF, Ejection fraction; SBP, Systolic blood pressure; DBP, Diastolic blood pressure

Discussion

The present study has developed a comprehensive model for estimating the risk of 3-year readmission after acute MI, showing an approximate readmission rate of 30%. According to our results, smoking, SI, ejection fraction, and the creatinine level were significant predictors of readmission for STEMI patients.

Most similar studies have considered a follow-up period of 30 days or 90 days. In the present study, patient follow-up was continued for 3 years, showing 1, 2, and 3-year readmission rates of 9.2%, 16.6%, and 30.27%, respectively.[8, 16] Khot et al[10] reported a readmission rate of 21.3% at least once within 12 months after acute MI. Andrés et al[17] conducted a similar study with an 8-year follow-up and reported readmission rates of 49.97% for patients <45 years and 38% for patients >75 years within 1 year and also readmission rates of 75.56% for patients <45 years and 72.34% for patients >75 years within 3 years.

We found that increased creatinine levels were associated with higher readmission rates in STEMI patients, which is supported by Song et al,[18] who reported renal dysfunction and consequently higher creatinine levels as predictors for readmission in acute MI patients within 12 months and in STEMI patients within 30 days, respectively. This finding is also consistent with a study by Uluganyan et al, who reported significantly higher in-hospital and long-term major adverse cardiac events (MACE) and, consequently, readmissions in patients with estimated glomerular filtration rates <60 mL/min/1.73 m.[2] This finding may be explained by various and excessive drugs used by these patients. Renal dysfunction can also accelerate the process of atherosclerosis and, thereby, readmission, but the definite reason is not yet known.[19]

Smoking was another critical risk factor associated with increased readmission rates in STEMI patients. Kini et al[9] also reported the role of smoking in the 90-day risk of readmission after acute MI. Carbon monoxide and nicotine increase plaque formation in blood vessels, which can result in coronary artery disease and readmission in the long term. The present study also showed that 55.9% of readmitted men were smokers. However, it should be noted that we had fewer female patients than male patients, and women had lower smoking rates than men. Another study has reported a similar result.[20]

In the present study, heart rate had no significant association with readmission rates in STEMI patients. Nevertheless, Wang et al[21] reported that patients in the subgroup with resting heart rates >76 bpm had a significantly higher incidence of MACE than patients with resting heart rates between 61 bpm and 76 bpm. Moreover, there was no significant difference in the risk of MACE between the subgroups with resting heart rates <61 bpm and resting heart rates between 61 bpm and 76 bpm in the study. Both elevation and reduction in heart rate are risk factors for MACE, as Sun et al[22] reported that both heart rates <65 and ≥80 bpm increase MACE risks in hypertensive patients, compared with patients with heart rates of 70 to 74 bpm.

Okkonen et al[23] reported that heart failure was an important risk factor of MACE after the first acute coronary syndrome, supporting the present study's findings. The mechanism of this association has yet to be determined, but it may be due to frailty. Frailty is an age-related syndrome associated with increased vulnerability and decreased resistance to stressors, proven to be overrepresented in heart failure patients.[24] Heart failure is also associated with the risk of other prognostic factors, such as cancer, diabetes, and renal failure.[25-27]

Reinstadler et al[28] reported elevated SI as a factor associated with reduced MACE-free survival, which opposes the present study's findings. SI integrates both heart rate and systolic blood pressure and can be a better predictor compared with these 2 hemodynamic parameters alone as a risk factor.[29]

The present study has several limitations. Firstly, the results are presented from a single tertiary referral center receiving STEMI patients from Isfahan Province in Iran; thus, the present study's findings may not be generalized as all single data source studies. Additionally, unmeasured factors may be associated with readmission during the index admission or post-discharge. The strengths of the present study include 3 years of patient follow-up, which is remarkable compared with similar studies. Moreover, a comprehensive database is used in the present study, which is large enough to be justifiable. Additionally, our data are homogeneous and gathered meticulously, improving the reliability of the findings.

Conclusion

The readmission rate of patients during the 3-year follow-up in our study was about one-third, which is remarkable. Due to its remarkable costs, the readmission rate has attracted extensive attention from health policymakers and insurance agents. It is recommended that general practitioners and cardiologists pay special attention to these factors in the routine visits of patients. It is also suggested that patients use secondary preventive cardiac rehabilitation programs to better control risk factors that lower readmission rates.

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