Factors Influencing In-Hospital and Long-Term Mortality in Patients with Acute ST-Elevation Myocardial Infarction Undergoing Primary Percutaneous Intervention

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Abstract

Objective: To identify factors associated with in-hospital and long-term mortality among patients with ST-elevation myocardial infarction (STEMI) undergoing primary percutaneous coronary intervention (PCI) in a regional hospital in Thailand.

Materials and Methods: This retrospective cohort study analyzed patients with STEMI who received primary PCI from January 2014 to December 2022. Demographic characteristics, clinical presentation, angiographic findings, procedural details, and clinical outcomes were extracted from medical records. The primary outcome was long-term all-cause mortality during a 3-year follow-up period. Survival probabilities were estimated using the Kaplan-Meier method, and Cox proportional hazards regression assessed factors associated with long-term mortality. Statistically significant defined as $p<0.05$.

Results: The 283 patients with STEMI undergoing primary PCI were analyzed, with 12 (4.2%) dying during hospitalization. Long-term survival data included 270 patients. 3-year and 5-year survival rates were 81.0% and 78.4%, respectively. Non-survivors were older and presented with greater clinical severity. Kaplan-Meier analysis showed significantly lower survival among patients with Killip class III-IV and those who achieved a myocardial blush grade (MBG) ≤2 after PCI (log-rank $p<0.001$). Multivariable Cox regression, age >65 years, left ventricular dysfunction, mechanical ventilation, chronic obstructive pulmonary disease, a greater number of stents, and severe coronary calcification on angiography were independently associated with increased long-term mortality. In contrast, achievement of MBG 3 (adjusted HR 0.28, 95% CI 0.13-0.64, $p=0.002$), longer duration of dual antiplatelet therapy (adjusted HR 0.07, 95% CI 0.02-0.28, $p<0.001$), and eGFR 60-89 mL/minute/1.73 m^2 (adjusted HR 0.24, 95% CI 0.09-0.65, $p=0.005$) were independently associated with lower long-term mortality.

Conclusion: Long-term mortality remained substantial. Older age and greater clinical severity were associated with poorer outcomes, whereas achievement of MBG 3 was associated with improved long-term survival, highlighting the importance of early risk stratification and optimized reperfusion strategies

Keywords: Acute ST elevation; Primary percutaneous intervention; In-hospital mortality; Long-term mortality

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Acute myocardial infarction (AMI) remains a leading cause of morbidity and mortality worldwide, with ST-elevation myocardial infarction (STEMI) representing its most life-threatening presentation. STEMI is defined by persistent ST-segment elevation on electrocardiography in conjunction with elevated

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What is already known about this topic?

- Patients with STEMI continue to experience adverse outcomes during long-term follow-up despite treatment with primary PCI.
- Advanced age, left ventricular dysfunction, renal impairment, chronic obstructive pulmonary disease, and the need for mechanical ventilation have been reported as factors associated with increased mortality after STEMI.
- Angiographic lesion complexity and impaired myocardial perfusion have been associated with poorer procedural outcomes and increased risk of adverse events.
- Procedural and angiographic complications during PCI have been reported to be associated with increased mortality in patients with STEMI.

What does this study add?

- Severe coronary calcification identified on angiography was independently associated with long-term mortality in patients with STEMI undergoing PCI.
- This study provides real-world evidence from a regional referral hospital in Thailand, where patients presented with high baseline clinical severity.
- Procedural and angiographic complications were strongly associated with adverse long-term outcomes and were therefore analyzed separately from baseline predictors.
- The findings support the value of angiographic assessment and myocardial perfusion evaluation in long-term risk assessment after STEMI.

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cardiac biomarkers, most often resulting from plaque rupture and subsequent thrombotic occlusion of a coronary artery. Major traditional risk factors include tobacco use, dyslipidemia, hypertension, diabetes mellitus, and a family history of coronary artery disease, all of which contribute to the development and acute severity of STEMI[1-6]. Despite substantial advances in acute cardiac care and secondary prevention, STEMI continues to be complicated by heart failure, malignant arrhythmia and other major adverse cardiovascular events (MACE), underscoring the ongoing challenge of reducing its global burden.

In Thailand, nationally representative data on STEMI are scarce, but hospital-based registries highlight its clinical importance. For example, the Thai Registry in Acute Coronary Syndrome (TRACS) reported relatively low in-hospital mortality yet persistently high one-year mortality rates among STEMI patients, while recent analyses of different public health insurance schemes have revealed significant variability in outcomes[7,8]. More recently, data from the Thai percutaneous coronary intervention (PCI) registry, which included 22,741 PCI patients and more than 10,000 patients with acute coronary syndrome, provided contemporary national evidence on in-hospital outcomes after PCI across different medical funding schemes[9]. These findings suggest that regional disparities in healthcare access, emergency referral systems and the availability of primary PCI services may critically influence both short- and long-term survival in Thailand.

Primary PCI has emerged as the gold standard reperfusion strategy for STEMI, offering superior restoration of coronary blood flow, reduced infarct size, and lower reinfarction and mortality rates compared with fibrinolytic therapy[10-12]. Nonetheless, patients who develop cardiogenic shock, severe arrhythmias, or other periprocedural complications continue to experience unacceptably high mortality, even with adjunctive mechanical support devices such as intra-aortic balloon pumps, percutaneous cardiopulmonary support systems, and other circulatory assist technologies[5,6,13]. Numerous clinical and procedural factors—including advanced age, female sex, hyperglycemia on admission, prolonged door-to-balloon times and multivessel disease—have been identified as predictors of mortality[4,11,12,14-19]. Although risk-stratification tools and machine learning-based nomograms have been developed to predict outcomes after PCI, their accuracy and generalizability across diverse patient populations and healthcare contexts remain limited[14-17,19]. Reported in-hospital mortality rates for STEMI patients treated with primary PCI range from approximately 4% to 7% in high-volume centers, while one-year (long-term) mortality may reach 10% to 15%, depending on patient and system-level characteristics[4,15,20-23]. Due to ongoing challenges, region-specific data is needed to inform clinical decisions.

The present study aims to identify factors associated with both in-hospital and long-term mortality among patients with STEMI undergoing primary PCI in a regional hospital setting in Thailand. It will assess how patient comorbidities, procedural factors, and post-intervention complications affect outcomes, thereby improving early risk recognition and management of high-risk patients in resource-constrained settings.

Materials and Methods

This study employed a retrospective cohort design and was conducted at a regional referral hospital in Thailand. Patient data were obtained from hospital records, specifically from the cardiology and catheterization departments. The study population included consecutive patients who presented with acute STEMI and underwent primary PCI, with follow-up at the cardiology clinic between January 2014 and December 2022.

Inclusion criteria were: 1) patients diagnosed with STEMI who underwent primary PCI and 2) patients who had complete medical and follow-up records available at the cardiology clinic. Patients were excluded if they had STEMI due to non-coronary causes such as myocarditis, had incomplete clinical records, or received thrombolytic therapy prior to PCI.

Exposure variables were grouped into three main categories: patient characteristics (including age at symptom onset, sex, co-morbidities such as diabetes, hypertension, chronic kidney disease, and a prior history of ischemic heart disease), presentation characteristics at admission (for example, Killip class, hemodynamic parameters, and laboratory values), and angiographic and procedural characteristics (such as culprit vessel, pre- and post-PCI thrombolysis in myocardial infarction [TIMI] flow grade, number of diseased vessels, stent type, contrast volume, and fluoroscopy time). Data for these exposure variables were extracted retrospectively from electronic medical records and catheterization laboratory databases, ensuring standardized definitions and consistent measurement across all patients. The primary outcome was defined as long-term all-cause mortality at three years post-hospital discharge, verified through

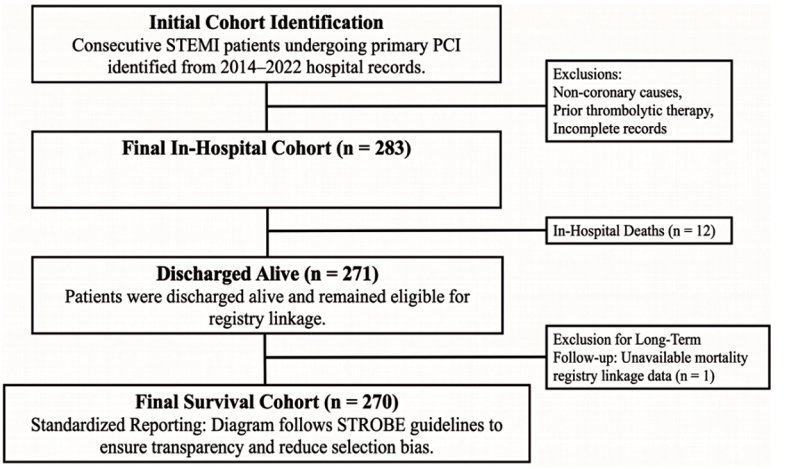


Figure 1. Patient flow diagram of the retrospective cohort of STEMI patients undergoing primary PCI.

STEMI=ST-elevation myocardial infarction; PCI=percutaneous coronary intervention

linkage with the National Civil Registration database. Secondary outcomes included in-hospital mortality (any death occurring before discharge) and PCI-related complications (such as reinfarction, stroke, urgent repeat revascularization, cardiogenic shock, and major bleeding as defined by BARC criteria).

Data collection was conducted using structured case record forms specifically developed for this study. Data entry was performed using EpiData version 4.7.0 (EpiData Association, Odense, Denmark). The study captured demographic and clinical characteristics, procedural details (e.g., access site, culprit lesion, thrombus grade, stent characteristics, TIMI and myocardial blush grade [MBG] flow grades), and clinical outcomes. Comorbid conditions were confirmed through review of clinical history and included cardiovascular disease, diabetes mellitus, hypertension, and dyslipidemia.

The sample size for this study was calculated using G*Power software to determine the minimum number of participants needed to assess predictors of long-term mortality among patients with STEMI undergoing primary PCI. The calculation was based on an expected odds ratio of 3.15 and a long-term mortality rate of 14.6%[24] with a two-tailed alpha level of 0.05 and a statistical power of 95%. These parameters indicated a required sample size of approximately 290 patients.

Statistical Analysis

Statistical analysis was performed using Stata/MP 18.0 (StataCorp LLC, College Station, TX, USA). Descriptive statistics and tabulations were used to summarize baseline demographic characteristics, procedural features, and adverse clinical outcomes. Continuous variables were reported as means and standard deviations or medians and interquartile ranges, depending on the data distribution. Categorical variables were expressed as counts and percentages.

The primary outcome was time-to-event data on all-cause mortality, analyzed using the Kaplan-Meier method to estimate survival patterns. Cox proportional hazards regression was used to evaluate associations between potential risk factors and long-term mortality. Variables with p-values less than 0.10 in univariable analyses, together with variables considered clinically relevant, were considered for inclusion in multivariable models. Killip classification violated the proportional hazards assumption; it was handled using a stratified Cox regression approach rather than being included as a covariate. Statistical significance was defined as a p-value less than 0.05.

Ethical Approval

The study protocol was reviewed and approved by the Hatyai Hospital Institutional Review Board (Protocol No. HYH EC-095-067-01) and was conducted in accordance with the principles outlined in the Declaration of Helsinki. Because this investigation involves a retrospective analysis of existing data, the requirement for informed consent was waived. During data extraction, all patient identifiers will be removed, and only anonymized study IDs will be retained in the final dataset.

Results

A total of 283 patients with STEMI undergoing primary PCI were included (Figure 1). Patients included in long-term survival analysis: 270/283

Table 1. Characteristics of non-survived and survived STEMI participants undergoing PCI over a 3-year follow-up period

Characteristics	Total (n=283)	Non-survived (n=72, 25.4%)	Survived (n=211, 74.6%)	p-value
Male; n (%)	212 (74.9)	50 (69.4)	162 (76.8)	0.215
Age (years); median (IQR)	64 (53, 75)	70 (59.5, 78.2)	62 (52, 73)	<0.001
BMI (kg/m^2); median (IQR)	23.9 (21.3, 25.6)	24.2 (21.5, 25.5)	23.8 (21.2, 25.6)	0.310
Hypertension; n (%)	139 (49.3)	42 (59.2)	97 (46.0)	0.055
Dyslipidemia; n (%)	142 (50.5)	32 (45.1)	110 (52.4)	0.287
Diabetes mellitus; n (%)	66 (23.4)	23 (32.4)	43 (20.4)	0.039
Cerebrovascular disease; n (%)	21 (7.5)	8 (11.4)	13 (6.2)	0.146
Current/ex-smoker; n (%)	163 (57.8)	35 (49.3)	128 (60.7)	0.093
Chronic kidney disease; n (%)	43 (15.4)	14 (20.3)	29 (13.8)	0.196
eGFR (mL/minute/1.73 m^2); median (IQR)	67 (53.2, 88)	56.4 (40, 79)	69 (58, 90.5)	0.007
COPD; n (%)	15 (5.3)	7 (9.9)	8 (3.8)	0.065

STEMI=ST-elevation myocardial infarction; PCI=percutaneous coronary intervention; BMI=body mass index; IQR=interquartile range; eGFR=estimated glomerular filtration rate; COPD=chronic obstructive pulmonary disease

(95.4%). During the 3-year follow-up period, 72 patients (25.4%) died, while 211 patients (74.6%) survived.

Baseline Characteristics and Clinical Presentation

Non-survivors were significantly older than survivors (median age 70 vs. 62 years, p<0.001) and had a higher prevalence of diabetes mellitus (32.4% vs. 20.4%, p=0.039). Hypertension was more common among non-survivors (59.2% vs. 46.0%, p=0.055), while smoking status showed a borderline association with mortality (p=0.093).

Markers of disease severity at presentation differed markedly between groups. Non-survivors are more frequently presented with prolonged ischemic time >120 minutes (97.2% vs. 88.0%, p=0.024) and higher Killip class at presentation (p<0.001), particularly Killip class IV (80.6% vs. 41.4%). The incidence of cardiac arrest (50.8% vs. 17.9%, p<0.001), left ventricular dysfunction (EF <40%) (55.9% vs. 18.1%, p<0.001), use of high-dose inotropic drugs (43.1% vs. 6.6%, p<0.001), and mechanical ventilation (41.7% vs. 4.3%, p<0.001) were all significantly higher among non-survivors (Table 1, 2).

Angiographic and Procedural Characteristics

There was no significant difference in vascular access between groups (p=0.860). Left main culprit lesions were more common among non-survivors (11.3% vs. 2.0%, p=0.003), whereas right coronary artery (RCA) culprit lesions were more frequently observed among survivors (p=0.013). Multivessel disease was significantly more prevalent among non-survivors (85.7% vs. 67.5%, p=0.003).

Thrombectomy was performed less frequently in non-survivors (62.5% vs. 78.1%, p=0.009). Post-PCI reperfusion was significantly poorer among non-survivors, with lower achieved TIMI flow grades (p<0.001) and MBGs (p<0.001). Procedural success was also slightly lower among non-survivors (93.1% vs. 98.6%, p=0.028) (Table 3).

Survival Analysis and Long-Term Mortality

In-hospital mortality was 4.2% (12 of 283 patients). Kaplan-Meier survival analysis estimated 3-year and 5-year overall survival probabilities of 81.0% (95% CI 75.8 to 85.2) and 78.4% (95% CI 72.7 to 83.0), respectively, among patients with STEMI undergoing primary PCI (Figure 2). When stratified by clinical severity at presentation, overall survival differed significantly between patients with Killip class I-II and class III-IV, with markedly poorer survival observed in those presenting with higher Killip class (log-rank p<0.001) (Figure 3A). Patients achieving a MBG of grade 3 had significantly higher survival probabilities than those with lower MBG grades (log-rank p<0.001) throughout the 3-year follow-up period (Figure 3B).

In univariable Cox proportional hazards analysis, several clinical and procedural factors were significantly associated with long-term mortality. Patients aged >65 years had a higher risk of death during follow-up compared with younger patients (crude HR 2.43, 95% CI 1.27 to 4.67, p=0.007). Left ventricular dysfunction was associated with increased long-term mortality (crude HR 3.90, 95% CI 2.33 to 6.51, p<0.001), as were the need for mechanical ventilation (crude HR 5.95, 95% CI 3.56 to 10.21, p<0.001) and the presence of chronic obstructive pulmonary disease (crude HR 2.47, 95% CI 1.12 to 5.43, p=0.025). Each additional

Table 2. Clinical findings at presentation of non-survived and survived STEMI participants undergoing PCI over a 3-year follow-up period

Clinical findings at presentation	n (%)			p-value
	Total (n=283)	Non-survived (n=72, 25.4%)	Survived (n=211, 74.6%)	
Ischemic time >120 minutes	253 (90.4)	69 (97.2)	184 (88.0)	0.024
Killip classification at presentation*				<0.001
I	83 (29.4)	4 (5.6)	79 (37.6)	
II	37 (13.1)	4 (5.6)	33 (15.7)	
III	17 (6.0)	6 (8.3)	11 (5.2)	
IV	145 (51.4)	58 (80.6)	87 (41.4)	
Cardiac arrest	69 (25.6)	32 (50.8)	37 (17.9)	<0.001
Arrythmia	112 (39.7)	35 (49.3)	77 (36.5)	0.057
LV dysfunction (EF <40%)	74 (27.7)	38 (55.9)	36 (18.1)	<0.001
Mechanical circulatory support†	22 (7.8)	17 (23.6)	5 (2.4)	<0.001
High dose of inotropic drugs	128 (45.4)	51 (71.8)	77 (36.5)	<0.001
High dose of inotropic drugs				<0.001
Single inotropic drug	56 (45.5)	13 (26.0)	43 (58.9)	
Double inotropic drug	67 (54.5)	37 (74.0)	30 (41.1)	
Ventilator support	93 (33.1)	51 (71.8)	42 (20.0)	<0.001
Duration of dual antiplatelet therapy$				<0.001
<6 months	61 (21.7)	58 (80.6)	3 (1.4)	
6-12 months	20 (7.1)	4 (5.6)	16 (7.7)	
1-2 years	77 (27.4)	8 (11.1)	69 (33.0)	
2-3 years	122 (43.4)	2 (2.8)	120 (57.4)	
>3 years	1 (0.4)	0 (0.0)	1 (0.5)	

STEMI=ST-elevation myocardial infarction; PCI=percutaneous coronary intervention; LV=left ventricular; EF=ejection fraction; DAPT=dual antiplatelet therapy; MCS=mechanical circulatory support; IABP=intra-aortic balloon pump; ECMO=extracorporeal membrane oxygenation

* Killip classification was assessed at initial presentation, † Mechanical circulatory support was defined as the use of IABP and/or ECMO, $ DAPT was defined as aspirin plus a P2Y12 inhibitor

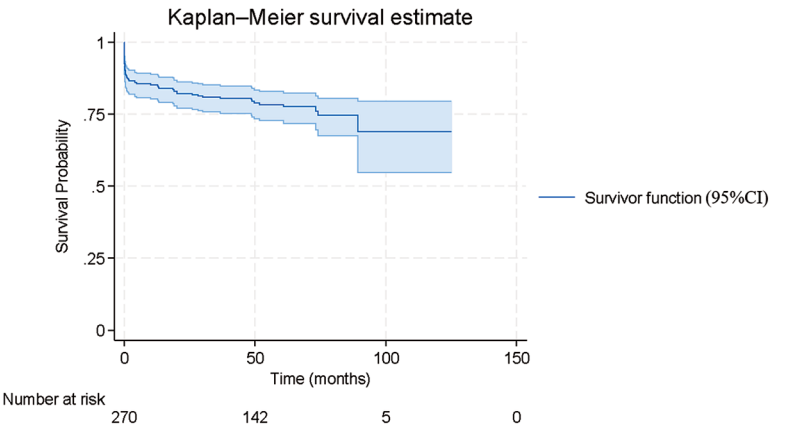


Figure 2. Kaplan-Meier estimate of overall survival among patients with ST-elevation myocardial infarction undergoing primary percutaneous coronary intervention.

coronary stent implanted was associated with higher long-term mortality (crude HR 1.62, 95% CI 1.16 to 2.26, p=0.005). In contrast, achieving MBG 3 was associated with a substantially lower risk of long-term mortality (crude HR 0.09, 95% CI 0.05 to 0.18, p<0.001). A longer duration of dual antiplatelet therapy, up to 2 years, was also associated with reduced long-term mortality (crude HR 0.03, 95% CI 0.01 to 0.13, p<0.001).

After adjustment for relevant clinical and procedural covariates, age >65 years remained independently associated with increased long-term

Table 3. Angiographic and procedural characteristics of participants and mortality outcome over a 3-year follow-up period

Angiographic and procedural characteristics	n (%)			p value
	Total (n=283)	Non-survived (n=72, 25.4%)	Survived (n=211, 74.6%)	
PCI access				0.860
Femoral	239 (85.4)	61 (84.7)	178 (85.6)	
Radial	41 (14.6)	11 (15.3)	30 (14.4)	
Left main culprit lesion	12 (4.5)	8 (11.3)	4 (2.0)	0.003
LAD culprit lesion	128 (46.9)	39 (54.9)	89 (44.1)	0.114
RCA culprit lesion	114 (42.1)	21 (29.6)	93 (46.5)	0.013
Multivessel disease	201 (72.0)	60 (85.7)	141 (67.5)	0.003
TIMI flow of culprit vessel				0.715
TIMI 0	211 (74.8)	51 (70.8)	160 (76.2)	
TIMI 1	32 (11.3)	10 (13.9)	22 (10.5)	
TIMI 2	31 (11.0)	8 (11.1)	23 (11.0)	
TIMI 3	8 (2.8)	3 (4.2)	5 (2.4)	
Thrombus grading				0.184
Grade 0	7 (2.5)	2 (2.8)	5 (2.4)	
Grade 1	61 (21.6)	17 (23.6)	44 (20.9)	
Grade 2	31 (11.0)	13 (18.1)	18 (8.5)	
Grade 3	23 (8.1)	6 (8.3)	17 (8.1)	
Grade 4	31 (11.0)	9 (12.5)	22 (10.4)	
Grade 5	130 (45.9)	25 (34.7)	105 (49.8)	
LVEDP measurement	35 (13.0)	8 (12.1)	27 (13.3)	0.805
Thrombectomy	209 (74.1)	45 (62.5)	164 (78.1)	0.009
Direct stent	57 (20.4)	9 (12.5)	48 (23.2)	0.053
Angiography showed heavy calcified	20 (7.1)	10 (13.9)	10 (4.8)	0.010
Cutting balloon or Angio sculpt	7 (2.5)	5 (7.0)	2 (1.0)	0.013
PCI to non-infarct artery	12 (4.3)	6 (8.3)	6 (2.9)	0.083
Number of stents				0.007
0	21 (7.9)	7 (10.3)	14 (7.1)	
1	149 (56.0)	28 (41.2)	121 (61.1)	
2	75 (28.2)	22 (32.4)	53 (26.8)	
3	20 (7.5)	10 (14.7)	10 (5.1)	
4	1 (0.4)	1 (1.5)	0 (0.0)	
Type of drugs				0.003
Sirolimus	55 (21.2)	8 (12.1)	47 (24.2)	
Biolimus	77 (29.6)	20 (30.3)	57 (29.4)	
Everolimus	66 (25.4)	13 (19.7)	53 (27.3)	
Zotalimus	23 (8.8)	6 (9.1)	17 (8.8)	
Hybrid drugs	39 (15.0)	19 (28.8)	20 (10.3)	
Number of stents overlap				0.051
0	190 (67.9)	41 (56.9)	149 (71.6)	
1	75 (26.8)	24 (33.3)	51 (24.5)	
2	13 (4.6)	6 (8.3)	7 (3.4)	
3	2 (0.7)	1 (1.4)	1 (0.5)	
Success PCI for STEMI	273 (97.2)	67 (93.1)	206 (98.6)	0.028
Stage PCI	31 (11.5)	3 (4.3)	28 (14.1)	0.027
Achieve TIMI grade				<0.001
TIMI 0	6 (2.1)	5 (6.9)	1 (0.5)	
TIMI 1	10 (3.5)	7 (9.7)	3 (1.4)	
TIMI 2	74 (26.2)	28 (38.9)	46 (21.9)	
TIMI 3	192 (68.1)	32 (44.4)	160 (76.2)	
MBG grade				<0.001
MBG 0	12 (4.3)	9 (12.5)	3 (1.4)	
MBG 1	32 (11.3)	20 (27.8)	12 (5.7)	
MBG 2	86 (30.5)	27 (37.5)	59 (28.1)	
MBG 3	152 (53.9)	16 (22.2)	136 (64.8)	

STEMI=ST-elevation myocardial infarction; PCI=percutaneous coronary intervention; LAD=left anterior descending artery; RCA=right coronary artery; TIMI=thrombolysis in myocardial infarction; LVEDP=left ventricular end-diastolic pressure; MBG=myocardial blush grade

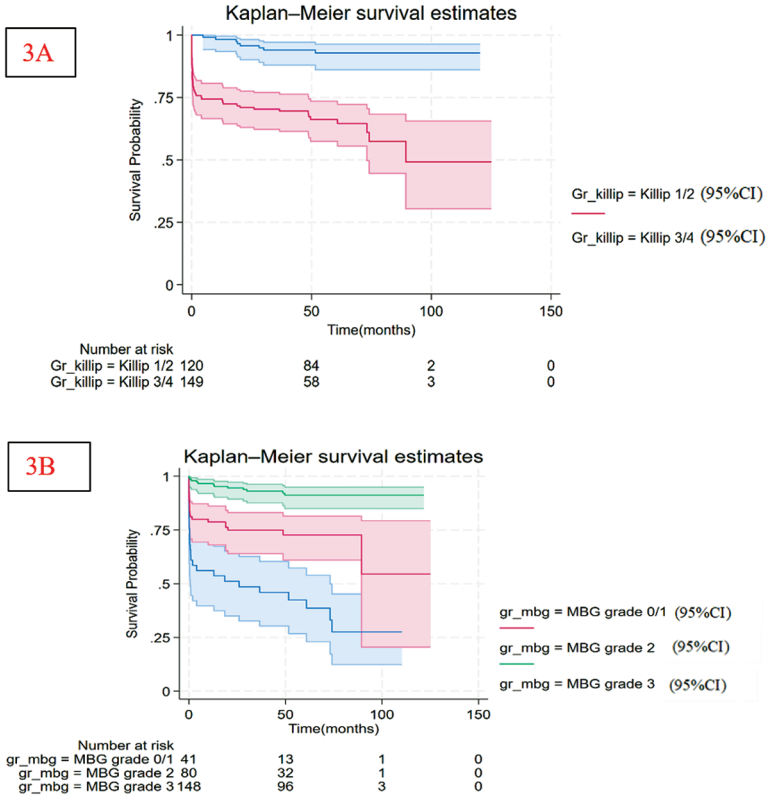


Figure 3. Kaplan-Meier curves of overall survival stratified by Killip classification (3A) and myocardial blush grade (3B) among patients with ST-elevation myocardial infarction undergoing primary percutaneous coronary intervention (log-rank test p<0.001).

mortality (adjusted HR 2.90, 95% CI 1.43 to 5.89, p=0.003), as did left ventricular dysfunction (adjusted HR 2.20, 95% CI 1.14 to 4.27, p=0.019). Mechanical ventilation continued to show a strong independent association with long-term mortality (adjusted HR 3.39, 95% CI 1.67 to 6.88, p=0.001), and chronic obstructive pulmonary disease remained associated with an increased risk of long-term death (adjusted HR 4.06, 95% CI 1.31 to 12.53, p=0.015). The number of coronary stents implanted also remained significantly associated with long-term mortality after adjustment (adjusted HR 1.50, 95% CI 1.06 to 2.10, p=0.021).

Achievement of MBG grade 3 remained independently associated with lower long-term mortality (adjusted HR 0.28, 95% CI 0.13 to 0.64, p=0.002). An association between estimated glomerular filtration rate (eGFR) 60-89 mL/minute/1.73 m² and reduced long-term mortality was observed after adjustment (adjusted HR 0.24, 95% CI 0.09 to 0.65, p=0.005), whereas the association for eGFR 45-59 mL/minute/1.73 m² did not reach statistical significance (adjusted HR 0.34, 95% CI 0.10 to 1.20, p=0.094). A longer duration of dual antiplatelet therapy remained independently associated with reduced long-term mortality (adjusted HR 0.07, 95% CI 0.02 to 0.28, p<0.001). The presence of severe coronary calcification on angiography remained associated with long-term mortality after multivariable adjustment (adjusted HR 2.79, 95% CI 1.12 to 6.96, p=0.028) (Table 4).

Procedural Complications

Angiographic and procedural complications occurred in 24 patients during the study period (Table 5). Complications were more frequently observed among non-survivors than survivors (66.7% vs. 33.3%), and the occurrence of any complication was associated with a significantly higher risk of long-term mortality (crude HR 5.50, 95% CI 3.00 to 10.07, log-rank p<0.001). The most common complications after PCI included dissection and post-procedural cardiogenic shock. Rare but severe complications, such as coronary perforation requiring emergency pericardiocentesis, stroke, heart failure, and cardiac arrest, occurred exclusively in the non-survivor group.

Table 4. Factors associated with long-term mortality among participants undergoing primary PCI over a 3-year follow-up period

	Crude HR (95% CI)	p-value	Adjusted HR† (95% CI)	p-value
Age >65 (years)*	2.43 (1.27 to 4.67)	0.007	2.90 (1.43 to 5.89)	0.003
Left ventricular dysfunction	3.90 (2.33 to 6.51)	<0.001	2.20 (1.14 to 4.27)	0.019
Number of stents	1.62 (1.16 to 2.26)	0.005	1.50 (1.06 to 2.10)	0.021
MBG grade 3‡	0.09 (0.05 to 0.18)	<0.001	0.28 (0.13 to 0.64)	0.002
eGFR 60-89 (mL/minute/1.73 m^2)§	0.65 (0.32 to 1.30)	0.224	0.24 (0.09 to 0.65)	0.005
eGFR 45-59 (mL/minute/1.73 m^2)§	0.96 (0.38 to 2.44)	0.929	0.34 (0.10 to 1.20)	0.094
Ventilator	5.95 (3.56 to 10.21)	<0.001	3.39 (1.67 to 6.88)	0.001
COPD	2.47 (1.12 to 5.43)	0.025	4.06 (1.31 to 12.53)	0.015
longer duration of dual antiplatelet therapy ≥2 years	0.03 (0.01 to 0.13)	<0.001	0.07 (0.02 to 0.28)	<0.001
Severe coronary calcification on angiography	2.49 (1.18 to 5.26)	0.016	2.79 (1.12 to 6.96)	0.028

PCI=percutaneous coronary intervention; HR=hazard ratio; CI=confidence interval; MBG=myocardial blush grade; eGFR=estimated glomerular filtration rate; COPD=chronic obstructive pulmonary disease

† Adjusted for age, left ventricular dysfunction, number of stents, myocardial blush grade, estimated glomerular filtration rate, mechanical ventilation, chronic obstructive pulmonary disease, duration of antiplatelet therapy, and coronary angiography

* Reference group: Age <55 years, ‡ Reference group: MBG grades 0, § Reference group: eGFR ≥90 mL/minute/1.73 m^2

Table 5. Complications of angiography and procedures among STEMI participants undergoing PCI over a 3-year follow-up period

Event	Total (n=24)	n (%)	
		Non-survived (n=16)	Survived (n=8)
Complications*	24	16 (66.7)	8 (33.3)
Perforation	2	2 (100)	0 (0.0)
• Emergency pericardiocentesis	1	1 (100)	0 (0.0)
Dissection	8	6 (75.0)	2 (25.0)
• Slow flow	6	5 (83.33)	1 (16.67)
• No reflow	1	1 (100)	0 (0.0)
Post-procedural cardiogenic shock	10	8 (80.0)	2 (20.0)
Heart failure	1	1 (100)	0 (0.0)
CVA/stroke	1	1 (100)	0 (0.0)
Bleeding	2	1 (50.0)	1 (50.0)
• Access site, size >3 cm	1	0 (0.0)	1 (100)
• GI bleed	1	1 (100)	0 (0.0)
Cardiac arrest	1	1 (100)	0 (0.0)

STEMI=ST-elevation myocardial infarction; PCI=percutaneous coronary intervention; CVA=cerebrovascular accident; GI=gastrointestinal; HR=hazard ratio; CI=confidence interval

* Crude HR 5.50 (95% CI 3.00 to 10.07), log-rank test p<0.001

Discussion

In this study of patients with STEMI undergoing primary PCI in a regional hospital in Thailand, approximately one-quarter of patients died during the 3-year follow-up period. The findings highlight the central importance of clinical severity at presentation and quality of post-procedural reperfusion in determining long-term survival in real-world practice. Advanced age, left ventricular dysfunction, chronic obstructive pulmonary disease, need for mechanical ventilation, greater number of implanted stents, and the presence of severe coronary calcification on angiography were associated with a higher risk of death during follow-up. In contrast, achieving a MBG of 3 or higher and a longer duration of dual antiplatelet therapy were associated with lower long-term mortality. Procedural and angiographic complications were also strongly associated with adverse long-term outcomes.

An important feature of this cohort was the high proportion of patients presenting with advanced clinical severity. More than half of patients with available Killip classification presented with Killip class IV, and this was substantially more frequent among non-survivors than survivors. This finding suggests that our cohort included a large proportion of high-risk STEMI patients, including those with cardiogenic shock or severe hemodynamic compromise at presentation. Therefore, the observed mortality outcomes should be interpreted in the context of this high baseline clinical severity and may not be directly comparable with lower-risk primary PCI cohorts. This finding is consistent with previous evidence showing that higher Killip class is an important prognostic marker among patients with acute myocardial infarction undergoing primary PCI[6]. Nevertheless, because door-to-wire/balloon time, diagnosis-to-wire/balloon time, and exact continuous ischemic time were not systematically available, we could not determine the extent to which treatment delay contributed to these outcomes.

Clinical and Angiographic Predictors of Long-Term Mortality

Consistent with previous studies[14,15]. Age >65 years and left ventricular dysfunction remained strong predictors of long-term mortality after adjustment

for relevant covariates. These findings underscore the persistent prognostic impact of baseline patient vulnerability and impaired cardiac function beyond the acute phase of STEMI. The association between chronic obstructive pulmonary disease and mortality may reflect the combined effects of systemic inflammation, reduced cardiopulmonary reserve, and higher procedural complexity[3,14,15].

The presence of severe coronary calcification on angiography was independently associated with long-term mortality. Severe calcification is known to complicate lesion preparation, stent deployment, and optimal expansion, and has been associated with suboptimal procedural outcomes and increased risk of adverse events[14,18,19]. Our findings suggest that angiographic evidence of heavy calcification carries prognostic significance beyond the index procedure and may identify a subgroup of patients at increased long-term risk.

Myocardial Perfusion and Microvascular Recovery

Achievement of MBG grade 3 was strongly and independently associated with lower long-term mortality. Unlike epicardial flow measures, MBG reflects microvascular reperfusion at the myocardial tissue level[25,26]. Our results support the concept that effective microvascular recovery following PCI is a key determinant of long-term survival[24-26].

Renal Function and Long-Term Outcomes

An association between eGFR 60-89 mL/minute/1.73 m² and lower long-term mortality was observed after multivariable adjustment, whereas the association for eGFR 45-59 mL/minute/1.73 m² did not reach statistical significance. This finding should be interpreted with caution and may reflect residual confounding, patient selection, or complex interactions among renal function, comorbidity burden, and survival in this cohort. Importantly, reduced renal function remains a recognized marker of cardiovascular risk[3,14,15]. Further studies are warranted to clarify its role in long-term outcomes following STEMI.

Antiplatelet Therapy and Long-Term Survival

A longer duration of dual antiplatelet therapy, up to two years, remained independently associated with reduced long-term mortality. This observation is consistent with evidence supporting the role of sustained platelet inhibition in preventing recurrent ischemic events following STEMI[10,11,15]. Nevertheless, treatment duration may also reflect patient adherence, clinical stability, and physician judgment and should therefore be interpreted as an association rather than a causal effect.

Procedural Complications and Long-Term Mortality

Procedural and angiographic complications were strongly associated with long-term mortality. These events likely reflect both procedural complexity and underlying disease severity[5,6,13,18,19]. However, because such complications occur during or after PCI and may lie on the causal pathway between baseline risk factors and mortality, they were analyzed separately rather than included in the primary multivariable model. This approach avoids over-adjustment and allows clearer interpretation of baseline and angiographic predictors of long-term outcomes.

This study has several limitations. Its retrospective observational design limits causal inference and is subject to residual confounding. Data on door-to-wire/balloon time, diagnosis-to-wire/balloon time, and total ischemic time were not systematically available in this retrospective cohort. Although prolonged ischemic time (>120 minutes) was available and reported, exact continuous ischemic time was not consistently available; therefore, the full impact of treatment delay on short-term and long-term outcomes could not be comprehensively assessed. The single-center setting may limit generalizability, and the small number of events in certain subgroups reduces statistical power for detailed analyses. In addition, information on post-discharge management and long-term medication adherence was not available. Despite these limitations, the study provides valuable real-world evidence from a regional hospital setting that reflects routine clinical practice in resource-constrained environments.

Conclusion

In patients with STEMI undergoing primary PCI in a regional hospital setting, long-term mortality remained substantial. Older age, greater clinical severity at presentation, and suboptimal post-procedural reperfusion were associated with poorer outcomes, whereas achieving TIMI grade 3 after PCI was associated with improved long-term survival. These findings underscore the importance of early risk stratification and optimization of reperfusion strategies to improve outcomes among high-risk STEMI patients, particularly in resource-limited settings.

Authors' Contributions

Conceptualization: SW and HT; Data curation: KK and HT; Formal analysis: KK, HT, and SS; Investigation: SW; Methodology: SW and HT; Project

administration: SW; Resources: SW; Software: KK, HT, and SS; Supervision: SW and HT; Validation: SW and HT; Visualization: SW, HT, and SS; Writing-original draft preparation: HT; Writing-review and editing: SW, HT, SS, and KK. All authors have read and agreed to the published version of the manuscript.

Clinical Trial Registration

Not applicable due to the retrospective design of the study.

Conflicts of Interest

The authors declare that they have no conflicts of interest related to this work. No financial or personal relationships influenced the study design, data collection, analysis, or manuscript preparation.

Data Availability Statement

The data supporting the findings of this study are not publicly available due to ethical and institutional restrictions. Data may be available from the corresponding author upon reasonable request and with approval from the relevant Institutional Review Board.

Ethics Approval and Consent to Participate

This study was approved by the Hatyai Hospital Institutional Review Board (Protocol No. HYH EC-095-067-01) in the year 2025 and was conducted in accordance with the principles outlined in the Declaration of Helsinki. Because this investigation involves a retrospective analysis of existing data, the requirement for informed consent was waived.

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Use of Artificial Intelligence

ChatGPT (OpenAI) was used to improve the readability and language of the revised manuscript. The authors reviewed and approved the final manuscript.

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