



Clinical Determinants and Predictive Modeling of Fibrinolytic Success in Non-Diabetic STEMI Patients Using Logistic Regression and CART Analysis

Andi Heri Isman¹, Abdul Hakim Alkatiri¹, Akhtar Fajar Muzakkir¹

¹Department of Cardiology, Faculty of Medicine, Hasanuddin University, Makassar, Indonesia

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KEYWORDS

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ABSTRACT:

Introduction: Fibrinolytic therapy remains an essential reperfusion strategy for ST-segment elevation myocardial infarction (STEMI) in settings where primary percutaneous coronary intervention is not readily available. However, the determinants of successful fibrinolysis and the role of predictive modeling in non-diabetic populations remain incompletely understood.

Objectives: This study aimed to identify clinical determinants and develop a predictive model of fibrinolytic success in non-diabetic STEMI patients using logistic regression and classification and regression tree (CART) analysis.

Methods: A retrospective cohort study was conducted among non-diabetic STEMI patients who received fibrinolytic therapy at a tertiary referral hospital between 2018 and 2025. The primary outcome was successful fibrinolysis, defined as $\geq 50\%$ ST-segment resolution within 60–90 minutes with clinical improvement. Bivariate and multivariable logistic regression analyses were performed to identify independent predictors. CART analysis was used to explore hierarchical relationships and predictive performance.

Results: A total of 182 patients were included, with a fibrinolytic success rate of 73.6%. Early symptom-to-treatment time (< 6 hours) was independently associated with higher success (adjusted OR 3.98; 95% CI 1.45–10.92; $p=0.007$). Clopidogrel loading therapy was also a significant predictor (adjusted OR 3.21; 95% CI 1.12–9.18; $p=0.029$). CART analysis identified symptom-to-treatment time as the primary determinant, followed by antiplatelet therapy, with moderate predictive performance.

Conclusions: Fibrinolytic success in non-diabetic STEMI patients is primarily determined by timely treatment and adjunctive antiplatelet therapy. Predictive modeling using CART provides additional insights into variable interactions and may support clinical decision-making in resource-limited settings.

1. Introduction

ST-segment elevation myocardial infarction (STEMI) remains a major contributor to global cardiovascular morbidity and mortality, resulting from acute occlusion of a coronary artery and subsequent transmural myocardial ischemia.^[1] Early restoration of coronary blood flow is essential to preserve myocardial viability and improve clinical outcomes. Although primary percutaneous coronary intervention (PCI) is the preferred reperfusion strategy, its availability is often limited in many low- and middle-income countries. Consequently, fibrinolytic therapy continues to play a critical role as an accessible and time-sensitive treatment option in these settings.^[2,3]

The effectiveness of fibrinolytic therapy is influenced by multiple clinical factors, with treatment delay being one of the most important determinants.^[4] The concept of “time is muscle” emphasizes that prolonged ischemia leads to irreversible myocardial damage and reduced likelihood of successful reperfusion.^[5] In addition to timing, other variables such as patient characteristics, baseline cardiovascular risk factors, and adjunctive pharmacological therapy may also contribute to variations in fibrinolytic outcomes. However, the relative contribution of these factors remains variable across different populations.^[6]

Diabetes mellitus is known to affect vascular biology and fibrinolytic pathways, often resulting in impaired



reperfusion and worse clinical outcomes in STEMI patients.^[7] The presence of a prothrombotic state, endothelial dysfunction, and altered platelet activity in diabetic individuals may confound the relationship between clinical variables and fibrinolytic success.^[8] Therefore, evaluating a non-diabetic population provides a more homogeneous clinical setting to better understand the intrinsic determinants of fibrinolytic effectiveness without the influence of metabolic disturbances.^[9]

In recent years, there has been increasing interest in the application of predictive modeling to enhance clinical decision-making in cardiovascular diseases.^[10] Traditional statistical approaches such as logistic regression are widely used to identify independent predictors of clinical outcomes. However, these methods may not fully capture complex interactions between variables. Machine learning approaches, including classification and regression tree (CART) analysis, offer an alternative framework by identifying hierarchical relationships and providing intuitive decision rules that may improve risk stratification in clinical practice.^[11, 12]

In this context, the present study aimed to identify clinical determinants and develop a predictive model of fibrinolytic success in non-diabetic STEMI patients. By combining conventional statistical analysis with CART-based modeling, this study seeks to provide a more comprehensive understanding of factors influencing reperfusion outcomes. The findings are expected to support clinical decision-making and optimize fibrinolytic strategies, particularly in resource-limited settings where timely and effective treatment remains a critical challenge.

2. Objectives

The objective of this study was to identify the clinical determinants associated with fibrinolytic success and to develop a predictive model for reperfusion outcomes in non-diabetic patients with ST-segment elevation myocardial infarction (STEMI). Specifically, this study aimed to evaluate the role of key clinical variables, including symptom-to-treatment time and adjunctive antiplatelet therapy, using multivariable logistic regression analysis, and to explore their hierarchical interactions and predictive performance through classification and regression tree (CART) analysis.

3. Methods

This study was an observational analytical study with a retrospective cohort design conducted at a tertiary referral hospital in Makassar, Indonesia. Medical records of patients diagnosed with ST-segment elevation myocardial infarction (STEMI) who received fibrinolytic therapy between January 2018 and December 2025 were reviewed. Eligible patients were adults aged ≥ 18 years with a confirmed diagnosis of STEMI who underwent fibrinolysis and had no documented history of diabetes mellitus. Patients with significant structural heart disease, severe systemic illness, or incomplete clinical data were excluded. Ethical approval for the study was obtained from the institutional review board, and all data were anonymized prior to analysis.

The primary exposure variable was symptom-to-treatment time, defined as the interval between onset of chest pain and initiation of fibrinolytic therapy, categorized as < 6 hours and ≥ 6 hours. The primary outcome was successful fibrinolysis, defined as $\geq 50\%$ resolution of ST-segment elevation within 60–90 minutes after therapy, accompanied by clinical improvement and/or reperfusion arrhythmias.^[13, 14] Additional variables included demographic characteristics, cardiovascular risk factors, and initial pharmacological therapy, particularly antiplatelet administration. Data were extracted systematically from medical records and entered into a structured database for analysis.

Statistical analysis was performed using SPSS version 29.0 and R software. Categorical variables were presented as frequencies and percentages. Bivariate analysis was conducted using the Chi-square or Fisher's exact test as appropriate, with results expressed as odds ratios (ORs) and 95% confidence intervals (CIs). Variables with p -values < 0.10 and those considered clinically relevant were included in multivariable logistic regression to identify independent predictors of fibrinolytic success, reported as adjusted odds ratios (aORs). In addition, classification and regression tree (CART) analysis was performed to explore hierarchical relationships among predictors and to develop a predictive model. Model performance was assessed using accuracy, sensitivity, specificity, and area under the receiver operating characteristic curve (AUC).



4. Results

A total of 182 non-diabetic patients with ST-segment elevation myocardial infarction (STEMI) who underwent fibrinolytic therapy were included in this study. Overall, successful fibrinolysis was achieved in 134 patients (73.6%), while 48 patients (26.4%) experienced failed reperfusion. The study population was

predominantly male and consisted mainly of patients under 60 years of age. Various cardiovascular risk factors and baseline clinical characteristics were observed across the cohort, along with differences in initial treatment strategies. The baseline demographic and clinical characteristics of the study population stratified by fibrinolytic outcome are presented in Table 1.

Table 1. Baseline Characteristics of Non-Diabetic STEMI Patients According to Fibrinolytic Outcome

Variable	Total (n=182)	Successful (n=134)	Failed (n=48)	p-value
Symptom-to-treatment time, n (%)				
<6 hours	49 (26.9)	44 (32.8)	5 (10.4)	0.003
≥6 hours	133 (73.1)	90 (67.2)	43 (89.6)	
Sex, n (%)				
Male	157 (86.3)	117 (87.3)	40 (83.3)	0.492
Female	25 (13.7)	17 (12.7)	8 (16.7)	
Age, n (%)				
<60 years	132 (72.5)	102 (76.1)	30 (62.5)	0.238
≥60 years	50 (27.5)	32 (23.9)	18 (37.5)	
Hypertension, n (%)				
Yes	89 (48.9)	64 (47.8)	25 (52.1)	0.607
No	93 (51.1)	70 (52.2)	23 (47.9)	
Obesity, n (%)				
Yes	75 (41.2)	57 (42.5)	18 (37.5)	0.518
No	106 (58.2)	76 (56.7)	30 (62.5)	
Clopidogrel loading, n (%)				
Yes	165 (90.7)	126 (94.0)	39 (81.3)	0.017
No	17 (9.3)	8 (6.0)	9 (18.7)	
History of angina, n (%)				
Yes	53 (29.1)	41 (30.6)	12 (25.0)	0.464
No	129 (70.9)	93 (69.4)	36 (75.0)	
Prior myocardial infarction, n (%)				
Yes	8 (4.4)	7 (5.2)	1 (2.1)	0.683
No	173 (95.1)	126 (94.0)	47 (97.9)	
Heart failure, n (%)				
Yes	4 (2.2)	2 (1.5)	2 (4.2)	0.285
No	174 (95.6)	129 (96.3)	45 (93.8)	

Data are presented as n (%). P-values were calculated using Chi-square or Fisher's exact test as appropriate.

As shown in Table 1, most patients presented with delayed symptom-to-treatment time (≥6 hours), and this group had a higher proportion of failed fibrinolysis compared to those presenting earlier. Early presentation (<6 hours) was more frequently associated with successful reperfusion. The majority of patients were male, with no significant difference in sex distribution

between groups. Similarly, age, hypertension, and obesity were not significantly associated with fibrinolytic outcome. However, the administration of clopidogrel loading therapy was significantly higher among patients with successful fibrinolysis. Other clinical variables, including history of angina, prior



myocardial infarction, and heart failure, did not show significant differences between the two groups.

To further evaluate the association between clinical variables and fibrinolytic success, a bivariate analysis was performed. This analysis aimed to identify potential factors associated with successful reperfusion and to

screen variables for inclusion in the multivariable logistic regression model. Each independent variable was analyzed in relation to fibrinolytic outcome, with the strength of association expressed as odds ratios and corresponding confidence intervals. The results of the bivariate analysis of factors associated with fibrinolytic success are presented in Table 2.

Table 2. Bivariate Analysis of Factors Associated with Fibrinolytic Success

Variable	Successful n (%)	Failed n (%)	OR (95% CI)	p-value
Symptom-to-treatment time				
<6 hours	44 (89.8)	5 (10.2)	4.20 (1.56–11.36)	0.003
≥6 hours	90 (67.7)	43 (32.3)	Reference	
Sex				
Male	117 (74.5)	40 (25.5)	1.38 (0.55–3.43)	0.492
Female	17 (68.0)	8 (32.0)	Reference	
Age group				
<45 years	23 (82.1)	5 (17.9)	—	0.238
45–59 years	79 (75.9)	25 (24.1)	—	
≥60 years	32 (64.0)	18 (36.0)	Reference	
Hypertension				
Yes	64 (71.9)	25 (28.1)	1.19 (0.61–2.30)	0.607
No	70 (75.3)	23 (24.7)	Reference	
Obesity				
Yes	57 (76.0)	18 (24.0)	0.80 (0.41–1.58)	0.518
No	76 (71.7)	30 (28.3)	Reference	
Clopidogrel loading (300 mg)				
Yes	126 (76.4)	39 (23.6)	3.63 (1.31–10.06)	0.017
No	8 (47.1)	9 (52.9)	Reference	
LDL level				
≥100 mg/dL	102 (77.3)	30 (22.7)	0.48 (0.23–1.01)	0.049
<100 mg/dL	26 (61.9)	16 (38.1)	Reference	
History of angina				
Yes	41 (77.4)	12 (22.6)	0.76 (0.36–1.60)	0.464
No	93 (72.1)	36 (27.9)	Reference	
Prior myocardial infarction				
Yes	7 (87.5)	1 (12.5)	0.38 (0.05–3.20)	0.683
No	126 (72.8)	47 (27.2)	Reference	
Heart failure				
Yes	2 (50.0)	2 (50.0)	2.87 (0.39–20.95)	0.285
No	129 (74.1)	45 (25.9)	Reference	

Data are presented as n (%). Odds ratios (OR) with 95% confidence intervals (CI) were calculated using bivariate analysis. P-values were derived from Chi-square or Fisher's exact test as appropriate.

As shown in Table 2, symptom-to-treatment time was significantly associated with fibrinolytic success, with patients presenting within 6 hours having a markedly

higher likelihood of achieving successful reperfusion compared to those with delayed presentation (OR 4.20; 95% CI 1.56–11.36; p=0.003). In addition, the



administration of clopidogrel loading therapy was significantly associated with improved outcomes, increasing the probability of successful fibrinolysis more than threefold (OR 3.63; 95% CI 1.31–10.06; $p=0.017$). LDL levels demonstrated a marginal association with fibrinolytic success ($p=0.049$), although the effect size was modest and approached the null value. Other variables, including sex, age, hypertension, obesity, history of angina, prior myocardial infarction, and heart failure, were not significantly associated with fibrinolytic outcomes in this analysis. These findings suggest that treatment timing and adjunctive antiplatelet therapy are key factors influencing fibrinolytic success and were

therefore included in the subsequent multivariable analysis.

To identify independent predictors of fibrinolytic success while accounting for potential confounding factors, a multivariable logistic regression analysis was performed. Variables that showed a p -value <0.10 in the bivariate analysis, along with those considered clinically relevant, were included in the model. This analysis aimed to determine which factors remained significantly associated with successful reperfusion after adjustment. The results of the multivariable logistic regression analysis identifying independent predictors of fibrinolytic success are presented in Table 3.

Table 3. Multivariable Logistic Regression Analysis of Factors Associated with Fibrinolytic Success

Variable	Adjusted OR (aOR)	95% CI	p-value
Symptom-to-treatment time <6 hours	3.98	1.45–10.92	0.007
Clopidogrel loading (300 mg)	3.21	1.12–9.18	0.029
LDL ≥ 100 mg/dL	0.61	0.28–1.32	0.210
Age ≥ 60 years	0.74	0.35–1.58	0.430
Hypertension	1.08	0.55–2.14	0.820

Adjusted odds ratios (aOR) with 95% confidence intervals (CI) were obtained from multivariable logistic regression analysis.

As shown in Table 3, early symptom-to-treatment time (<6 hours) remained a significant independent predictor of fibrinolytic success after adjustment for other variables (adjusted OR 3.98; 95% CI 1.45–10.92; $p=0.007$). Similarly, the administration of clopidogrel loading therapy was independently associated with improved reperfusion outcomes, increasing the likelihood of successful fibrinolysis more than threefold (adjusted OR 3.21; 95% CI 1.12–9.18; $p=0.029$). In contrast, LDL levels, age, and hypertension were not significantly associated with fibrinolytic success after multivariable adjustment. These findings indicate that timely treatment and adjunctive antiplatelet therapy are

the principal determinants of successful fibrinolysis in this population.

To further explore the hierarchical relationships and potential interactions among variables associated with fibrinolytic success, a classification and regression tree (CART) analysis was performed. This approach was used as an exploratory predictive modeling method to complement the findings from logistic regression and to provide a more intuitive representation of decision pathways in clinical practice. The structure of the CART model illustrating the predictors of fibrinolytic success is presented in Figure 1.

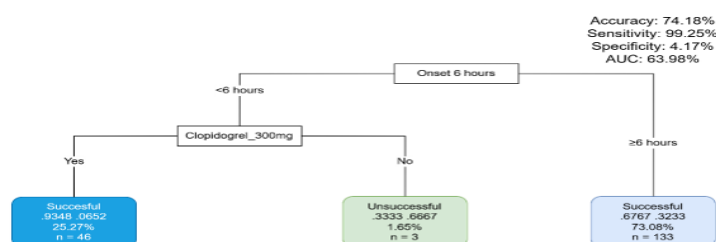


Figure 1. Classification and Regression Tree (CART) Analysis for Predicting Fibrinolytic Success in Non-Diabetic ST-Segment Elevation Myocardial Infarction Patients



As shown in Figure 1, the CART model identified symptom-to-treatment time as the primary splitting variable, indicating its dominant role in determining fibrinolytic success. Patients presenting within 6 hours of symptom onset demonstrated a substantially higher probability of successful reperfusion compared to those with delayed presentation. Among early presenters, further stratification by clopidogrel loading therapy revealed a higher likelihood of successful fibrinolysis in patients who received antiplatelet loading. In contrast, for patients with delayed presentation (≥ 6 hours), no additional meaningful splits were observed, suggesting that treatment delay may outweigh the influence of other clinical variables in this subgroup.

The overall performance of the CART model demonstrated moderate predictive ability, with acceptable accuracy and sensitivity but limited specificity. These findings support the results of the multivariable analysis and highlight the hierarchical importance of treatment timing and adjunctive antiplatelet therapy in predicting fibrinolytic outcomes.

5. Discussion

This study demonstrates that symptom-to-treatment time is the primary determinant of fibrinolytic success in non-diabetic patients with ST-segment elevation myocardial infarction (STEMI). Patients who presented within 6 hours of symptom onset had a significantly higher likelihood of achieving successful reperfusion compared to those with delayed presentation. In addition, the administration of clopidogrel loading therapy was independently associated with improved fibrinolytic outcomes. The findings from CART analysis further reinforced these results by identifying symptom-to-treatment time as the most important predictor, followed by adjunctive antiplatelet therapy.^[15]

The strong association between early treatment and fibrinolytic success can be explained by the dynamic evolution of intracoronary thrombus. In the early phase of STEMI, the thrombus is relatively less organized and more susceptible to fibrinolytic agents. As time progresses, the thrombus undergoes structural stabilization with increased fibrin cross-linking and platelet aggregation, reducing its responsiveness to lysis. Prolonged ischemia also contributes to microvascular obstruction and distal embolization, which may limit effective myocardial reperfusion even after restoration of

epicardial blood flow.^[16] These mechanisms support the concept that timely intervention is critical in optimizing fibrinolytic efficacy.

In addition to treatment timing, the use of clopidogrel loading therapy was found to significantly enhance fibrinolytic success.^[14] This finding is consistent with the known role of platelet activation in the formation and stabilization of coronary thrombi. Clopidogrel, through inhibition of the P2Y₁₂ receptor, reduces platelet aggregation and may facilitate thrombus dissolution when used in combination with fibrinolytic agents. The synergistic effect of fibrinolysis and antiplatelet therapy may also improve microvascular perfusion and reduce the risk of re-occlusion.^[17, 18] These results highlight the importance of optimal adjunctive pharmacological therapy in improving reperfusion outcomes.

The incorporation of CART analysis in this study provides additional insights into the hierarchical relationships among clinical variables influencing fibrinolytic success. Unlike traditional regression models, CART offers a more intuitive and clinically applicable decision-making framework by identifying key splitting variables and their interactions. In this study, the CART model confirmed the dominant role of symptom-to-treatment time and demonstrated its interaction with antiplatelet therapy. However, the predictive performance of the model was modest, indicating that while CART can complement conventional statistical analysis, it should be interpreted as an exploratory tool rather than a definitive predictive model.^[19]

These findings have important clinical implications, particularly in resource-limited settings where primary PCI is not readily available and fibrinolytic therapy remains a cornerstone of STEMI management. Efforts to reduce treatment delays through improved patient awareness, early diagnosis, and streamlined healthcare systems are essential to enhance outcomes. In addition, ensuring timely administration of adjunctive therapies such as clopidogrel may further optimize reperfusion success.^[20,21] This study has several limitations, including its retrospective design, potential selection bias, and reliance on clinical and electrocardiographic criteria without routine angiographic confirmation. Furthermore, the single-center setting may limit generalizability. Despite these limitations, the study



provides valuable insights into key determinants and predictive factors of fibrinolytic success in a non-diabetic population.

6. Conclusion

Fibrinolytic success in non-diabetic patients with ST-segment elevation myocardial infarction is primarily determined by early symptom-to-treatment time and the use of adjunctive antiplatelet therapy, particularly clopidogrel loading. Multivariable analysis confirmed these factors as independent predictors of successful reperfusion, while CART-based modeling further highlighted their hierarchical importance and interaction. These findings emphasize the critical role of timely intervention and optimized pharmacological management in improving reperfusion outcomes, especially in settings where primary PCI is not readily available.

Conflict Of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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