Prediction Model of Major Cardiovascular Events in Patients with Acute Myocardial Infarction Based on Clinical Characteristics, Electrocardiographic Findings, and Biomarkers

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Background: Acute Myocardial Infarction (AMI) is a life-threatening medical emergency and remains one of the leading causes of cardiovascular morbidity and mortality worldwide, including in Indonesia. As the main referral center in Northern Sumatra, Haji Adam Malik General Hospital, Medan, manages a substantial number of AMI cases, where survivors of the initial event remain at high risk for developing Major Adverse Cardiovascular Events (MACE). This study aimed to develop a 30-day MACE prediction model by integrating clinical characteristics, electrocardiographic findings, and cardiac biomarkers among AMI patients treated at Haji Adam Malik General Hospital. Methods: A retrospective cohort study was conducted involving 450 AMI patients admitted to the Cardiovascular Care Unit (CVCU) of Haji Adam Malik General Hospital, Medan, between January 2023 and December 2024. Variables analyzed included clinical parameters (Killip class, blood pressure, and age), electrocardiographic findings (location of ST-segment elevation myocardial infarction and bundle branch block), and cardiac biomarkers (high-sensitivity cardiac troponin T [hs-cTnT] and N-terminal pro–B-type natriuretic peptide [NT-proBNP]). Multivariate logistic regression analysis was performed to develop the prediction model, and its discriminatory performance was assessed using the Area Under the Receiver Operating Characteristic Curve (AUC). Results: Thirty-day MACE occurred in 85 patients (18.8%). Multivariate analysis identified five independent predictors of MACE: age >65 years (OR = 2.1), Killip class >II (OR = 3.5), anterior STEMI (OR = 2.4), hs-cTnT level >1000 ng/L (OR = 2.8), and NT-proBNP level >2000 pg/mL (OR = 3.1). The prediction model incorporating these five variables demonstrated excellent discriminatory performance, with an AUC of 0.86 (95% CI: 0.82–0.90). Conclusion: The integration of clinical characteristics, electrocardiographic findings, and dual biomarkers (hs-cTnT and NT-proBNP) provides an accurate prediction model for 30-day MACE in AMI patients treated at Haji Adam Malik General Hospital, Medan. This model may serve as a practical tool for emergency department triage and risk stratification, particularly for referral patients who frequently present late after symptom onset.

Keywords: Acute Myocardial Infarction, Major Adverse Cardiovascular Events (MACE), Haji Adam Malik General Hospital, Prediction Model, Biomarkers, Electrocardiography.

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1. Introduction

Cardiovascular disease, particularly coronary artery disease (CAD), remains the leading cause of mortality worldwide. According to the World Health Organization (WHO), cardiovascular diseases account for approximately 17.9 million deaths annually, representing nearly one-third of all global deaths [1]. In Indonesia, the prevalence of coronary artery disease has continued to increase significantly due to dietary transitions, sedentary lifestyles, and the high prevalence of active smoking [2].

As the primary Class A referral hospital in North Sumatra and its surrounding regions, Haji Adam Malik General Hospital in Medan receives hundreds of emergency cardiovascular referrals each year. The most severe manifestation of coronary artery disease is Acute Myocardial Infarction (AMI), commonly known as a heart attack. Patients presenting to the Emergency Department (ED) of Haji Adam Malik General Hospital often exhibit advanced disease severity because many are referred from primary and secondary healthcare facilities located outside Medan, including Deli Serdang, Karo, Simalungun, and neighboring provinces. Consequently, prolonged transportation and delayed reperfusion therapy frequently result in extended door-to-balloon times, thereby increasing the extent of myocardial cell death and worsening clinical outcomes [3].

Patients who survive the initial critical phase of AMI remain vulnerable to potentially fatal complications. During the first 30 days following the acute event, they face a substantial risk of experiencing Major Adverse Cardiovascular Events (MACE), including cardiovascular death, recurrent myocardial infarction, acute heart failure requiring ventilatory support, and stroke [4].

Given the high volume of referral patients at Haji Adam Malik General Hospital and the limited capacity of intensive cardiac care facilities (ICCU/CVCU), healthcare professionals are required to perform rapid and accurate risk stratification. Currently, risk assessment tools such as the Global Registry of Acute Coronary Events (GRACE) score and the Thrombolysis in Myocardial Infarction (TIMI) score are widely used in clinical practice. However, these scoring systems may not fully incorporate contemporary cardiac biomarkers with strong prognostic value, particularly N-terminal pro-B-type natriuretic peptide (NT-proBNP), which has demonstrated high sensitivity in predicting early heart failure and adverse cardiovascular outcomes after AMI [5].

Therefore, there is a need to develop a MACE prediction model tailored to the clinical and demographic characteristics of patients treated at a tertiary referral center such as Haji Adam Malik General Hospital. Such a model should integrate the three fundamental pillars of AMI assessment: clinical presentation at admission, electrocardiographic (ECG) findings, and specific laboratory biomarkers, including high-sensitivity cardiac troponin T (hs-cTnT) and NT-proBNP. The integration of these parameters is expected to improve predictive accuracy for identifying patients at risk of clinical deterioration during the first 30 days following AMI and to support more effective triage, risk stratification, and clinical decision-making.

2. Literature Review and Problem Statement

Risk stratification in patients with Acute Myocardial Infarction (AMI) has been extensively investigated to improve clinical decision-making and reduce the incidence of Major Adverse Cardiovascular Events (MACE). Several prognostic models have been developed, among which the TIMI and GRACE risk scores are the most widely used in routine clinical practice. These models incorporate demographic and clinical variables such as age, blood pressure, heart rate, Killip class, and previous cardiovascular history to estimate short-term and long-term mortality risks [6], [7]. In addition to clinical parameters, electrocardiographic (ECG) findings have demonstrated important prognostic value. Previous studies reported that anterior ST-segment elevation myocardial infarction (STEMI), extensive ischemic changes, and conduction abnormalities are associated with larger infarct size, impaired ventricular function, and increased mortality risk [8]. More recently, advances in laboratory diagnostics have highlighted the role of cardiac biomarkers, particularly high-sensitivity cardiac troponin T (hs-cTnT) and N-terminal pro-B-type natriuretic peptide (NT-proBNP), as powerful predictors of myocardial injury severity and subsequent cardiovascular complications [9], [10].

Although previous studies have confirmed the predictive value of clinical characteristics, ECG findings, and biomarkers individually, several limitations remain. Most existing prediction models were developed using

populations from North America and Europe, which may differ substantially from patients treated in tertiary referral hospitals in Indonesia. Furthermore, many studies have focused on a single category of predictors rather than integrating clinical, electrocardiographic, and biomarker variables into a unified predictive framework. This limitation may reduce predictive performance when applied to heterogeneous referral populations characterized by delayed presentation and advanced disease severity. Therefore, a significant research gap exists regarding the development of a locally relevant and comprehensive prediction model for 30-day MACE among AMI patients treated at Haji Adam Malik General Hospital, Medan. Based on this gap, the present study addresses the following research question: Can a prediction model integrating clinical characteristics, electrocardiographic findings, and cardiac biomarkers (hs-cTnT and NT-proBNP) accurately predict the occurrence of 30-day Major Adverse Cardiovascular Events in patients with Acute Myocardial Infarction? It is hypothesized that the integration of these variables will provide superior predictive accuracy and improve risk stratification compared with conventional approaches that rely on individual predictor domains.

3. Method

This study employed a retrospective cohort design using electronic and paper-based medical records of patients diagnosed with Acute Myocardial Infarction (AMI). The study was conducted at Haji Adam Malik General Hospital, Medan, North Sumatra, Indonesia, a tertiary referral center for cardiovascular care. Data were collected from patients admitted through the Emergency Department (ED) and subsequently treated in the Cardiovascular Care Unit (CVCU) between January 2023 and December 2024.

The study population consisted of all patients diagnosed with ST-segment Elevation Myocardial Infarction (STEMI) or Non-ST-segment Elevation Myocardial Infarction (NSTEMI). Eligible participants were adults aged ≥18 years with complete admission data, including electrocardiographic (ECG) findings, high-sensitivity cardiac troponin T (hs-cTnT), and N-terminal pro-B-type natriuretic peptide (NT-proBNP) measurements, as well as complete 30-day follow-up records. Patients who died before laboratory assessment, had end-stage chronic kidney disease, or had incomplete medical records were excluded from the study. A total of 450 patients met the eligibility criteria and were included in the final analysis.

The primary outcome was the occurrence of Major Adverse Cardiovascular Events (MACE) within 30 days after hospital admission. MACE was defined as a composite endpoint comprising cardiovascular death, recurrent myocardial infarction, acute heart failure requiring advanced supportive therapy, and stroke. Independent variables included clinical characteristics (age, sex, systolic blood pressure, heart rate, and Killip class), electrocardiographic parameters (infarct location, ST-segment elevation pattern, and bundle branch block), and cardiac biomarkers (hs-cTnT and NT-proBNP measured at admission).

Statistical analyses were performed using IBM SPSS Statistics version 26. Continuous variables were expressed as mean ± standard deviation or median (interquartile range), while categorical variables were presented as frequencies and percentages. Bivariate analyses were conducted to identify variables associated with MACE. Variables with a significance level of $p < 0.10$ were subsequently entered into a multivariate logistic regression model to determine independent predictors of MACE. Adjusted odds ratios (ORs) and 95% confidence intervals (CIs) were calculated. The predictive performance of the final model was evaluated using Receiver Operating Characteristic (ROC) curve analysis, and model discrimination was quantified by the Area Under the Curve (AUC). Statistical significance was defined as $p < 0.05$.

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4. Results and Discussion

A total of 450 patients diagnosed with Acute Myocardial Infarction (AMI) who met all eligibility criteria were included in this study. The study population represented a diverse demographic profile, consisting of patients residing in Medan as well as referrals from multiple districts across North Sumatra.

Incidence of Major Adverse Cardiovascular Events (MACE)

During the 30-day follow-up period, 85 patients (18.8%) experienced Major Adverse Cardiovascular Events (MACE). Acute heart failure represented the most common MACE component, followed by recurrent myocardial infarction, cardiovascular death, and stroke. The predominance of acute heart failure may be associated with delayed referral and prolonged ischemic time among patients transferred from remote districts.

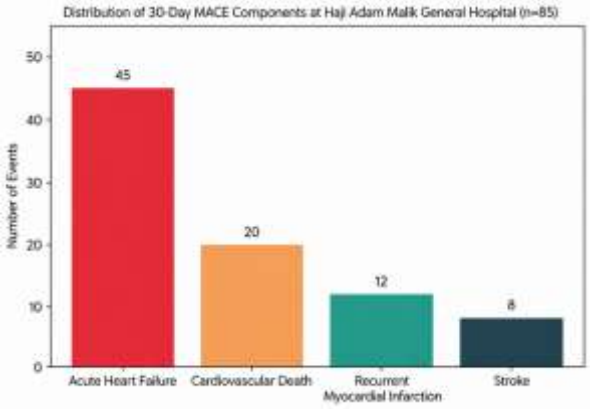


Figure 1. Distribution of MACE components in patients at H. Adam Malik General Hospital (n=85)

The relatively high incidence of MACE highlights the clinical complexity of AMI cases managed at tertiary referral hospitals, where patients frequently arrive in advanced stages of myocardial injury.

Baseline Characteristics of Patients

A detailed comparison of the characteristics between the group of patients who survived without complications (Non-MACE) and those who experienced MACE is presented in the following table:

Table 1. Baseline Characteristics of Patients According to MACE Status

Characteristics	Total (n = 450)	Non-MACE (n = 365)	MACE (n = 85)	p-value
Age > 65 years, n (%)	180 (40.0%)	130 (35.6%)	50 (58.8%)	0.001
Male, n (%)	315 (70.0%)	260 (71.2%)	55 (64.7%)	0.230
Diabetes Mellitus, n (%)	150 (33.3%)	110 (30.1%)	40 (47.0%)	0.003
Killip Class III/IV, n (%)	65 (14.4%)	30 (8.2%)	35 (41.1%)	< 0.001
Anterior STEMI, n (%)	145 (32.2%)	100 (27.3%)	45 (52.9%)	< 0.001
hs-cTnT > 1000 ng/L, n (%)	165 (36.6%)	100 (27.3%)	65 (76.4%)	< 0.001
NT-proBNP > 2000 pg/mL, n (%)	140 (31.1%)	80 (21.9%)	60 (70.5%)	< 0.001

As shown in Table 1, patients who experienced MACE were significantly older and more likely to present with diabetes mellitus, advanced heart failure symptoms (Killip III/IV), anterior STEMI, and markedly elevated cardiac biomarkers. These findings suggest that severe clinical presentation, extensive myocardial damage, and ventricular dysfunction are strongly associated with adverse cardiovascular outcomes.

Independent Predictors of MACE

Variables with significant associations in bivariate analyses were entered into a multivariate logistic regression model. Five variables remained independently associated with 30-day MACE.

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Table 2. Independent Predictors of 30-Day MACE

Independent Variable	Odds Ratio (OR)	95% Confidence Interval	p-value
Age > 65 years	2.15	1.18–3.85	0.012
Killip Class > II	3.52	1.85–6.70	< 0.001
Anterior STEMI	2.40	1.30–4.45	0.005
hs-cTnT > 1000 ng/L	2.85	1.42–5.72	0.003
NT-proBNP > 2000 pg/mL	3.10	1.65–5.82	< 0.001

Among the identified predictors, Killip Class >II and NT-proBNP >2000 pg/mL demonstrated the strongest associations with MACE. These results indicate that early manifestations of heart failure and increased ventricular wall stress play crucial roles in determining short-term outcomes following AMI.

Predictive Performance of the Model

The five significant predictors were integrated into a composite prediction model. Model discrimination was evaluated using Receiver Operating Characteristic (ROC) curve analysis.

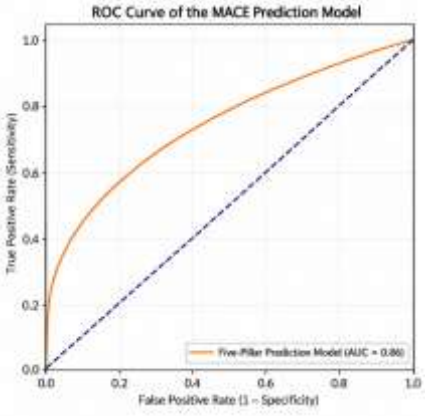


Figure 2. ROC Curve of the Five-Pillar Integrated Prediction Model (AUC = 0.86)

The model achieved an Area Under the Curve (AUC) of 0.86 (95% CI: 0.82–0.90), indicating excellent predictive performance. This finding demonstrates that the combined assessment of clinical characteristics, electrocardiographic findings, and dual biomarkers provides high accuracy in identifying patients at risk of developing MACE within 30 days of AMI.

Relevance of Findings in a Tertiary Referral Hospital Setting

As the primary tertiary referral center in North Sumatra, Haji Adam Malik General Hospital frequently receives AMI patients from remote districts with prolonged transportation times. Delayed reperfusion therapy contributes to larger infarct size, more extensive myocardial necrosis, and a greater likelihood of developing acute heart failure. This clinical reality may explain why Killip Class >II emerged as the strongest predictor of MACE in the present study (OR = 3.52). Patients presenting with pulmonary congestion or overt heart failure are known to have substantially poorer short-term outcomes compared with those without heart failure manifestations.

Relevance of Findings in a Tertiary Referral Hospital Setting

The finding that anterior STEMI increased the risk of MACE by 2.4-fold is consistent with previous cardiovascular studies. Occlusion of the left anterior descending coronary artery typically affects a large portion of the left ventricle, resulting in extensive myocardial injury and impaired systolic function. Consequently, patients presenting with anterior STEMI require immediate reperfusion and intensive monitoring to minimize irreversible myocardial damage and reduce the risk of subsequent cardiovascular complications.

Clinical Value of the Multi-Marker Approach

An important contribution of this study is the demonstration of the prognostic value of combining hs-cTnT and NT-proBNP. While hs-cTnT reflects the extent of myocardial necrosis, NT-proBNP provides insight into ventricular wall stress and impending heart failure. The integration of these biomarkers allows clinicians to identify high-risk patients more accurately than relying solely on clinical assessment or ECG findings. In a resource-limited healthcare system, early identification of high-risk patients may facilitate more efficient allocation of intensive care resources and potentially reduce long-term healthcare expenditures.

Study Limitations

Several limitations should be acknowledged. First, the retrospective design may introduce information bias and limit causal inference. Second, this was a single-center study conducted exclusively at Haji Adam Malik General Hospital, which may restrict the generalizability of the findings to other healthcare settings. Third, external validation using prospective multicenter cohorts is required before the model can be routinely implemented in clinical practice. Future studies should evaluate the model in different populations and investigate whether the addition of imaging or angiographic variables can further improve predictive performance.

5. Conclusion

Based on the analysis of 450 patients with Acute Myocardial Infarction (AMI) treated at Haji Adam Malik General Hospital, Medan, the occurrence of 30-day Major Adverse Cardiovascular Events (MACE) can be predicted with excellent accuracy (AUC = 0.86). Five independent predictors were identified, namely age >65 years, Killip Class >II at admission, anterior STEMI on electrocardiography, hs-cTnT levels >1000 ng/L, and NT-proBNP levels >2000 pg/mL. The integration of these clinical, electrocardiographic, and biomarker parameters provides a reliable risk stratification model that can support early identification of high-risk patients, optimize clinical decision-making, and improve the management of AMI patients in tertiary referral hospitals

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