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SVEAT score for early risk stratification of acute chest pain: a multicenter study

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Abstract

Background Chest pain is one of the most common reasons for emergency department (ED) visits. This study aimed to evaluate and compare the diagnostic performance of the SVEAT score for risk stratification in patients presenting to the ED with chest pain.

Methods This prospective, multicenter, observational study was conducted between June 1 and November 31, 2024. Adult patients presenting with chest pain were included. Exclusion criteria included trauma, pregnancy, STEMI diagnosis at presentation, unavailable follow-up, or missing data. Demographic characteristics, vital parameters, comorbidities, medications, and clinical outcomes were recorded. SVEAT and HEART scores were calculated at 0, 1, and 2 h based on original definitions. The primary outcome was the occurrence of MACE within 30 days.

Results A total of 704 patients were included (median age 46 years (IQR 33–61), 44.6% female). MACE occurred in 157 patients (22.3%). The area under the receiver operating characteristic curve (AUC) values for the SVEAT score at 0, 1, and 2 h were 0.954, 0.954, and 0.955, respectively, and for the HEART score were 0.935, 0.937, and 0.938, respectively. For the optimal cut-off value (SVEAT > 1), the sensitivity and specificity for MACE prediction were consistently 89% and 91% across all time points. For HEART > 2, the sensitivity was 89%, 91%, and 92%, with a constant specificity of 83%.

Conclusion The SVEAT score demonstrated excellent predictive accuracy for MACE at all time points and effectively discriminated between high- and low-risk patients with chest pain. The newly identified cut-off values enhance the safe identification of low-risk patients, potentially supporting earlier discharge decisions and optimizing ED resource utilization.

Clinical trial number Not applicable.

Keywords Chest pain, SVEAT score, HEART score, Emergency department, Risk stratification, Major adverse cardiac events

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Introduction

Chest pain remains one of the leading causes of emergency department (ED) presentations, accounting for an estimated 6–9 million acute-onset cases annually in the United States [1]. Due to its broad differential diagnosis, chest pain imposes a substantial burden on ED workflow and healthcare resources [2, 3]. Timely recognition of patients who will not require further diagnostic evaluation, treatment, or hospital resources is essential, as this strategy can both reduce unnecessary interventions and alleviate ED overcrowding [2]. The key clinical challenge lies in accurately identifying patients at low risk who can be discharged safely at an early stage [4]. Individuals without electrocardiographic evidence of ST-segment elevation or ischemia, and with a negative troponin value below the assay's lower limit of detection, are classified as having "low-risk chest pain" [5]. For this group, the 30-day post-discharge rate of major adverse cardiac events (MACE) is generally considered to be under 1% [5].

Over the years, multiple clinical algorithms, diagnostic tests, and scoring tools have been proposed to aid in differentiating, risk stratifying, and diagnosing patients presenting to the ED with chest pain [3, 6–10]. One of the most prominent of these is the HEART score, developed in 2008 specifically for ED chest pain risk assessment [11]. Incorporating five components—history, electrocardiography, age, risk factors, and troponin—the HEART score has gained widespread adoption in clinical practice due to its simplicity and practicality in the fast-paced ED environment [11–13].

Roongsritong et al. introduced the SVEAT score—a newly proposed scoring system designed to enhance risk assessment in patients presenting to the ED with chest pain [14]. This tool incorporates five domains: symptoms indicative of cardiovascular disease, prior vascular disease history, electrocardiographic abnormalities, patient age, and troponin measurement. Subsequent work by the same group and later by Gol et al. provided follow-up and independent external validation, respectively, further supporting its potential clinical utility [15, 16].

This study aimed to assess the diagnostic performance of the SVEAT score for risk stratification in patients presenting to the ED with chest pain.

Materials and methods

Study design and population

This prospective, multicenter observational study was carried out from June 1 to November 31, 2024, across the EDs of two participating centers: a tertiary university hospital and a secondary-level state hospital. At the time of the study, the city had two facilities capable of performing primary percutaneous coronary intervention (PCI), both of which were included. The tertiary university hospital had an approximate annual ED volume of 90,000 visits, while the secondary-level state hospital received around 360,000 visits annually. Both centers serve as regional referral institutions providing 24-hour emergency and primary PCI services, with cardiac-related complaints accounting for approximately 10–15% of all ED presentations. Ethical approval was obtained from the institutional review board before study commencement (Approval ID: 2024.05.30; Date: May 22, 2024). The study adhered to the ethical principles outlined in the Declaration of Helsinki.

Eligible participants were adults (≥ 18 years) presenting to the study centers during the study period with chest pain persisting for more than five minutes who provided written informed consent. Exclusion criteria included presentation due to trauma, pregnancy, a diagnosis of STEMI upon arrival, absence of vital signs at presentation, and incomplete clinical data.

Study setting

Patient demographic data, mode of arrival, comorbid diseases, medications, clinical outcomes, and all variables necessary for scoring calculations were prospectively documented using standardized, pre-structured case report forms.

Clinical data were extracted from electronic medical records and standardized written ED forms. Post-discharge 30-day MACE outcomes were ascertained through review of electronic medical records and direct contact with patients and/or their relatives via registered telephone numbers. Outcome assessment was performed by an investigator blinded to the scoring results and all index score components to minimize bias. Troponin measurements were performed using a high-sensitivity cardiac troponin I (hs-cTnI) assay (Abbott Architect Stat High Sensitive Troponin-I, Abbott Diagnostics, USA) uniformly across both centers. Following data collection, all information was entered into an electronic database for statistical analysis.

The primary outcome of the study was the development of MACE, defined as the presence of a primary diagnosis of NSTEMI or unstable angina pectoris at the index ED visit, or the occurrence within 30 days of a cardiac-related hospitalization, coronary revascularization (PCI or CABG), or all-cause mortality [14, 17].

Scores

The SVEAT score, developed by Roongsritong et al. in 2020, offers an alternative structured framework for risk assessment in chest pain presentations [14]. It comprises five variables: chest pain characteristics, history of vascular disease, electrocardiographic findings, age, and troponin level [14]. The total score ranges from – 7 to 15, with

scores ≤ 4 indicating low risk and scores >4 indicating high risk [14].

The HEART score, first introduced by Six et al. in 2008, is a rapid and practical tool for stratifying the risk of MACE in patients presenting with chest pain [9, 18]. It comprises five clinical components: patient history, electrocardiographic findings, age, cardiovascular risk factors, and troponin concentration [9]. The cumulative score ranges from 0 to 10, with risk categories defined as low (0–3 points), moderate (4–6 points), and high (7–10 points) [9].

Table 1 Baseline demographic and clinical characteristics of the patients

Variables, *n* (%)	Values (*n* = 704)
Gender, female	314 (44.6)
Age	46 (33–61)
Arrival	
Ambulatory	582 (82.7)
Ambulance	122 (17.3)
Comorbid diseases	
Coronary artery disease	199 (28.3)
Chronic heart failure	20 (2.8)
Arrhythmia	34 (4.8)
Hypertension	168 (23.9)
Diabetes Mellitus	111 (15.8)
Chronic renal disease	8 (1.1)
Chronic hepatic failure	1 (0.1)
Cerebrovascular disease	5 (0.7)
Medications	
Acetyl salicylic acid	117 (16.6)
Clopidogrel	51 (7.2)
Ticagrelor	3 (0.4)
Prasugrel	1 (0.1)
Dabigatran	1 (0.1)
Rivaroxaban	9 (1.3)
Apixaban	1 (0.1)
Edoxaban	3 (0.4)
Warfarin	16 (2.3)
Chest pain duration, min	180 (120–360)
Emergency length of stay, min	210 (190–230)
Disposition	
Discharge	553 (78.6)
Ward admission	10 (1.4)
ICU admission	69 (9.8)
Discharge against medical advice	72 (10.2)
Final diagnosis	
Non-STEMI	91 (12.9)
USAP	61 (8.7)
Non-specific	540 (76.7)
Other	12 (1.7)
MACE, Present	157 (22.3)

ICU: Intensive care unit, Non-STEMI: Non-ST-segment elevation myocardial infarction, USAP: Unstable angina pectoris, MACE: Major adverse cardiac event

Each scoring system was calculated at 0, 1, and 2 h after presentation, with the results documented in predesigned case report forms. All calculations were conducted in strict accordance with the definitions and criteria specified in the original development studies. To avoid bias, scoring was performed by an investigator blinded to all clinical outcomes.

Statistical analysis

The sample size was calculated based on the study by Gol et al., assuming a known proportion of 14.2%, an expected proportion of 10.0%, a margin of error of 0.05, and a statistical power of 80% [16]. This yielded a required sample size of 497 participants. To account for a potential 10% data loss, the target sample size was increased to 547 patients. The calculation was performed using an online sample size calculator (www.clincalc.com).

Continuous variables were summarized as mean ± standard deviation or median (IQR: interquartile range), and categorical variables as frequencies and percentages. Normality was tested with the Kolmogorov–Smirnov tests. Group comparisons were performed using the Student's t-test or the Mann-Whitney U test for continuous data, and the chi-square test for categorical data. ROC analysis was used to determine the discriminative ability of the scores, with AUC values, 95% Confidence Intervals (CIs), sensitivity, specificity, and predictive values reported. Optimal cut-offs were derived from the Youden index (J). Comparisons between ROC curves were conducted using the DeLong test. A two-tailed p-value of <0.05 was considered statistically significant. Analyses were performed using SPSS® v23.0 (IBM, Chicago, IL, United States).

Results

Between the study dates, 754 consecutive patients aged ≥ 18 years presenting to the participating centers with chest pain and providing informed consent were prospectively enrolled. Exclusion criteria included presentation due to trauma ($n = 10$), pregnancy ($n = 4$), STEMI at initial evaluation ($n = 15$), inability to obtain follow-up data after discharge ($n = 18$), and absence of vital signs upon arrival ($n = 3$). After applying these criteria, 704 patients remained for the final analysis.

The cohort had a median age of 46 years (IQR: 33–61), with 44.6% being female. Coronary artery disease (28.3%), hypertension (23.9%), and diabetes mellitus (15.8%) were the most frequently observed comorbidities. A total of 79 patients (11.2%) required hospitalization in general wards or intensive care units, whereas the remaining patients were discharged. Within 30 days, MACE occurred in 157 patients (22.3%). Detailed baseline characteristics and clinical outcomes are summarized in Table 1.

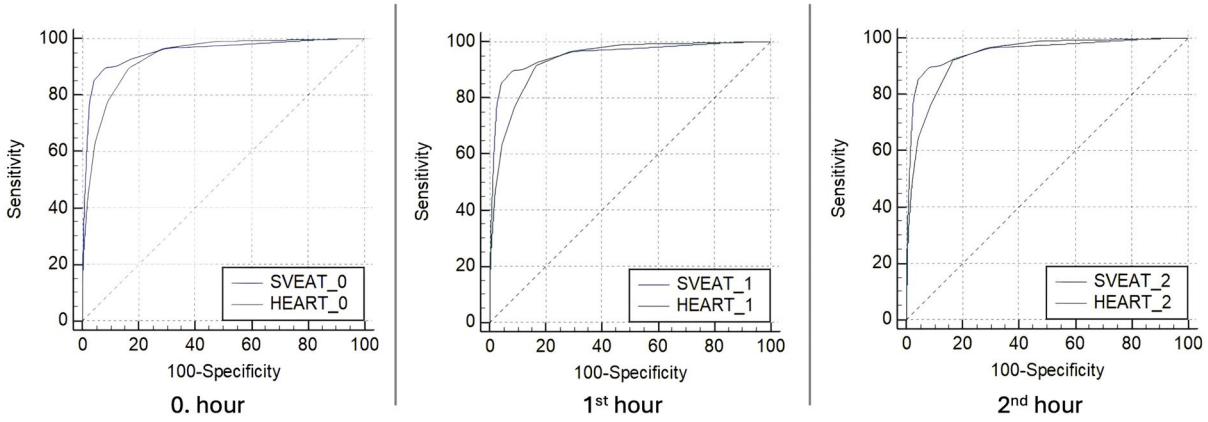

Fig. 1 ROC curves of the scores at different time points

Table 2 Performance of the scores at different cut-off values

Score	Cut-off	AUC	95% CI	Sensitivity	Specificity	PPV	NPV
SVEAT_0h	> 4*	0.954	0.936–0.969	61.8	98.2	90.7	89.9
SVEAT_1h	> 4*	0.954	0.936–0.969	62.4	98.2	90.7	90.1
SVEAT_2h	> 4*	0.955	0.937–0.969	63.1	98.2	90.8	90.3
HEART_0h	> 3*	0.935	0.914–0.952	77.7	91.0	71.3	93.4
HEART_1h	> 3*	0.937	0.916–0.954	77.1	91.0	71.2	93.3
HEART_2h	> 3*	0.938	0.917–0.955	77.1	91.0	71.2	93.3
SVEAT_0h	> 1**	0.954	0.936–0.969	89.8	91.7	75.8	96.9
SVEAT_1h	> 1**	0.954	0.936–0.969	89.8	91.7	75.8	96.9
SVEAT_2h	> 1**	0.955	0.937–0.969	89.8	91.7	75.8	96.9
HEART_0h	> 2**	0.935	0.914–0.952	89.8	83.3	60.8	96.6
HEART_1h	> 2**	0.937	0.916–0.954	91.7	83.3	61.3	97.2
HEART_2h	> 2**	0.938	0.917–0.955	92.3	83.3	61.4	97.4

AUC: Area under the curve, CI: Confidence interval; PPV: Positive predictive value, NPV: Negative predictive value. *original cut-off values, **newly derived cut-off values based on the Youden index

At presentation (0 h), both the SVEAT and HEART scores demonstrated excellent predictive performance for MACE, with AUC values of 0.954 (95% CI: 0.936–0.969) and 0.935 (95% CI: 0.914–0.952), respectively. Comparable performance was observed at 1 and 2 h.

At all measured time points, the ROC analysis revealed statistically significant differences between the SVEAT and HEART scores, with the SVEAT score consistently demonstrating superior discriminative performance for predicting MACE ($p < 0.05$, DeLong's test). Intra-score comparisons demonstrated similar discriminative performance between the 0–1 h and 1–2 h intervals, whereas a statistically significant divergence was identified between the 0- and 2-hour ROC curves (DeLong's test). Figure 1 presents the comparative ROC curves at each time point for both scoring systems.

When applying the original development study thresholds (SVEAT > 4 and HEART > 3), predictive performance was lower. For SVEAT > 4, sensitivities were 61.8%, 62.4%, and 63.1% at 0, 1, and 2 h, respectively, with corresponding specificities of 89.9%, 90.1%, and 90.3%. For HEART > 3, sensitivity remained constant at 77% and specificity at 91% across all three time points. A detailed summary of the predictive accuracy of the scoring systems for MACE at different cut-off points (original and newly introduced) is presented in Table 2.

Based on the Youden index (J point), the optimal cut-off values in our cohort were > 1 for the SVEAT score and > 2 for the HEART score. For SVEAT score > 1, sensitivity and specificity for MACE prediction were 89.8% and 91.7%, respectively, at all three time points (0, 1, and 2 h). For HEART score > 2, sensitivities of 89.8%, 91.7%, and 92.3% were observed at 0, 1, and 2 h, respectively, with a constant specificity of 83.3% across time points.

In our analysis, patients classified as low risk using SVEAT ≤1 had a 30-day MACE incidence of only 3.1% (16/518) at all time points. For HEART ≤2, MACE incidences among low-risk patients were 3.4% (16/472), 2.8% (13/469), and 2.6% (12/468) at 0, 1, and 2 h, respectively. In contrast, using the original SVEAT > 4 threshold,

Table 3 Risk stratification and MACE rates across different cut-off values

Score	Cut-off	Risk category	*n*	MACE Absent, *n* (%)	MACE Present, *n* (%)	*p*
SVEAT_0h	≤4*	Low	597	537 (98.2)	60 (38.2)	< 0.001
	> 4*	High	107	10 (1.8)	97 (61.8)	
	≤1**	Low	518	502 (91.8)	16 (10.2)	< 0.001
	> 1**	High	186	45 (8.2)	141 (89.8)	
SVEAT_1h	≤4*	Low	596	537 (98.2)	59 (37.6)	< 0.001
	> 4*	High	108	10 (1.8)	98 (62.4)	
	≤1**	Low	518	502 (91.8)	16 (10.2)	< 0.001
	> 1**	High	186	45 (8.2)	141 (89.8)	
SVEAT_2h	≤4*	Low	595	537 (98.2)	58 (36.9)	< 0.001
	> 4*	High	109	10 (1.8)	99 (63.1)	
	≤1**	Low	518	502 (91.8)	16 (10.2)	< 0.001
	> 1**	High	186	45 (8.2)	141 (89.8)	
HEART_0h	0–3*	Low	533	498 (91.0)	35 (22.3)	< 0.001
	4–6*	Moderate	125	45 (8.2)	80 (51.0)	
	7–10*	High	46	4 (0.7)	42 (26.8)	
	≤2**	Low	472	456 (83.4)	16 (10.2)	< 0.001
	> 2**	High	232	91 (16.6)	141 (89.8)	
HEART_1h	0–3*	Low	534	498 (91.0)	36 (22.9)	< 0.001
	4–6*	Moderate	122	45 (8.2)	77 (49.0)	
	7–10*	High	48	4 (0.7)	44 (28.0)	
	≤2**	Low	469	456 (83.4)	13 (8.3)	< 0.001
	> 2**	High	235	91 (16.6)	144 (91.7)	
HEART_2h	0–3*	Low	534	498 (91.0)	36 (22.9)	< 0.001
	4–6*	Moderate	117	44 (8.0)	73 (46.5)	
	7–10*	High	53	5 (0.9)	48 (30.6)	
	≤2**	Low	468	456 (83.4)	12 (7.6)	< 0.001
	> 2**	High	236	91 (16.6)	145 (92.4)	

MACE: Major adverse cardiac event, *original cut-off values, **newly derived cut-off values based on the Youden index

MACE incidences in low-risk patients were 10.1% (60/597), 9.9% (59/596), and 9.7% (58/537), while for the HEART original low-risk category (0–3 points), MACE incidences were 6.6% (35/533), 6.7% (36/534), and 6.7% (36/534) at the corresponding time points. Table 3 presents the risk stratification and corresponding MACE rates based on various cut-off thresholds for the scoring systems.

Discussion

Our findings indicate that SVEAT and HEART scores, when evaluated at 0, 1, and 2 h, are reliable tools for discriminating between high- and low-risk patients presenting to the ED with chest pain.

Previous research by Roongsritong et al. and Gol et al. demonstrated excellent overall performance for the SVEAT score (AUC: 0.982 and 0.916, respectively) and good-to-excellent performance for the HEART score (AUC: 0.921 and 0.856, respectively) [14, 16]. In contrast, other studies have reported good performance for the SVEAT score and moderate-to-good performance for the HEART score [15, 19, 20]. In the present study, both SVEAT and HEART scores exhibited excellent discriminative ability (AUC: 0.954 and 0.935, respectively). These findings support the use of both scoring systems as reliable tools for risk assessment in patients presenting to the ED with chest pain.

This study differs from previous literature by evaluating the predictive accuracy of scoring systems for MACE across multiple measurement time points. No prior research has investigated the temporal performance of the SVEAT score. In our analysis, each time-based recalculation incorporated both troponin values and concurrent electrocardiographic (ECG) findings to reflect the patient's clinical status at that specific hour. In contrast, Ras et al. found no differences between HEART scores calculated at different times, and Nilson et al. reported that HEART scores at 0 and 1 h could be used for safe discharge decisions in the ED [21, 22]. In our analysis, both SVEAT and HEART scores showed consistent predictive accuracy at 0, 1, and 2 h. These findings suggest that the choice of time point does not influence risk discrimination, allowing emergency physicians to apply either score confidently at any of these intervals for risk assessment and patient management in chest pain presentations.

Our study further differs from prior reports in that optimal cut-off values, defined according to the Youden index, deviated from those described in earlier literature. In the original derivation study, MACE rates among patients classified as low risk by the SVEAT and HEART scores were 0.8% and 1.4%, respectively [14]. Gol et al. reported comparable rates of 1% and 2.1% for these scores using the same thresholds [16]. In our analysis, applying the original cut-off values resulted in higher MACE rates (SVEAT: 9.7–10.1%, HEART: 6.6–6.7%). Conversely, implementation of the newly determined optimal cut-offs (>1 for SVEAT, >2 for HEART) lowered these rates to 3.1% and 2.6–3.4%, respectively. These results support the use of the new cut-offs to enhance the safety of discharge decisions for low-risk patients presenting with chest pain.

According to Gol et al., the sensitivities and specificities of the SVEAT and HEART scores with the original cut-off values were 94.7%/84.0% and 93.0%/53.1%, respectively [16]. In the present study, the SVEAT score computed at presentation yielded 61.8% sensitivity and 98.2% specificity at the original threshold, whereas application of the newly derived optimal cut-off (>1) resulted in 89.8% sensitivity and 91.7% specificity. This substantial improvement in sensitivity underscores the SVEAT score's enhanced rule-out capacity, which is critical for identifying patients at very low risk of acute coronary syndrome and safely excluding them from further invasive evaluation. This revised threshold significantly enhanced the ability to identify low-risk patients. Similar to prior evidence, our data indicate that the SVEAT score classifies a larger proportion of patients as low risk compared to the HEART score [14, 16]. From a clinical perspective, prioritizing sensitivity and negative predictive value over balanced accuracy aligns with the primary purpose of early risk stratification tools—to ensure patient safety while minimizing unnecessary admissions. Owing to its excellent overall performance and high sensitivity, the SVEAT score has the potential to support safe early discharge, thereby alleviating ED crowding, reducing unnecessary hospitalizations, optimizing resource allocation, and decreasing healthcare costs.

Previous research has demonstrated that derivation and external validation studies of identical scoring tools often report varying performance metrics. Discrepancies in patient populations, applied cut-off values, and heterogeneity in the definition and prevalence of MACE may account for these differences [23]. Such methodological and epidemiological variability limits the feasibility of direct head-to-head comparisons. Consequently, comparative evaluations should explicitly account for study-specific characteristics to ensure valid interpretations. In this context, the higher MACE rate observed in our cohort likely reflects the local patient profile and inclusion of all primary PCI-capable centers in the city, which predominantly manage higher-acuity chest pain cases. Moreover, inclusion of long-duration (>5 min) chest pain presentations may have further enriched the cohort with higher-risk patients. These factors likely contributed to the higher event rate and slightly increased number of missed MACEs in the low-risk category compared with other cohorts. This finding does not indicate inferior performance but rather reflects the higher-risk characteristics of the studied population. Therefore, the results should be interpreted within this context, and recommendations regarding clinical use are made cautiously, emphasizing population-specific applicability. Accordingly, our findings should not be viewed as evidence of superior performance but rather as supportive of the general utility of both scores within a high-risk ED population.

The relatively younger age profile of our study population likely reflects regional demographics and the inclusion of high-volume PCI-capable centers serving a large proportion of working-age patients. Moreover, because all patients with chest pain lasting more than five minutes were prospectively invited and only those providing informed consent were enrolled, a selection tendency toward younger participants may have occurred. This may have influenced absolute event rates and, consequently, score calibration, although the relative performance ranking of SVEAT and HEART scores remained consistent.

Limitations

This study has several limitations. First, both scoring systems incorporate subjective components, such as patient-reported history and clinician assessment of chest pain characteristics, which may introduce inter-observer variability and bias in score calculation. Second, the research was conducted in a single rural city, and although all PCI-capable centers in the region were included, the external generalizability of the findings to other populations or healthcare systems may be limited. Because these centers predominantly receive higher-acuity chest pain presentations, the study population represents a relatively high-risk ED cohort, which may account for the higher MACE incidence and could limit the applicability of our results to lower-acuity settings. Third, troponin measurements—an integral component of both the SVEAT and HEART scores—are time-dependent; variations in assay timing could have influenced score values and, consequently, risk stratification performance. Moreover, variability in troponin assay types and threshold definitions across studies or healthcare settings may influence the classification of myocardial injury and affect the apparent diagnostic performance of these scoring systems. Future multicenter investigations with standardized biomarker

sampling protocols and more diverse patient populations are warranted to validate and extend these findings.

Conclusion

Both the SVEAT and HEART scores, when calculated at 0, 1, and 2 h after ED presentation, demonstrated excellent overall performance in predicting MACE and reliably discriminated between high- and low-risk patients within this higher-risk ED population. The newly identified optimal cut-off values were associated with lower MACE rates in the low-risk group compared with the original derivation thresholds, suggesting potential improvement in discharge safety. The SVEAT score identified a greater proportion of patients as low risk without a meaningful loss of sensitivity, which may support earlier discharge decisions and more efficient ED resource use. These findings should, however, be interpreted with caution and within the clinical context of a higher-risk ED cohort. Multicenter studies across diverse populations are warranted to confirm the generalizability and clinical impact of these results.

Abbreviations

ED	Emergency department
MACE	Major adverse cardiac event
PCI	Percutaneous coronary intervention
IQR	Interquartile range
CI	Confidence interval
AUC	Area under the curve

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Author contributions

ZK: Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation, Data curation, Conceptualization. Bİ: Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation, Data curation, Conceptualization, Visualization, Validation. MK: Writing – review & editing, Methodology, Investigation, Data curation, Conceptualization. FB: Writing – review & editing, Methodology, Investigation, Data curation, Conceptualization. OE: Writing – review & editing, Methodology, Investigation, Data curation, Conceptualization. TD: Writing – review & editing, Project administration, Visualization, Validation, Supervision.

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Data availability

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethical approval and consent to participate

The institutional review board of Kırıkkale University Faculty of Medicine approved the study (Approval ID: 2024.05.30; Date: May 22, 2024).

Informed consent

was obtained from all participants.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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