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RESEARCH

Comparison of acute coronary syndrome decision aids in the emergency department

Acil serviste akut koroner sendrom karar yardımcılarının karşılaştırılması

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Abstract

Purpose: This study compared the performance of the Emergency Department Assessment of Chest Pain Score (EDACS), History, Electrocardiography, Age, Risk Factors, Troponin (HEART), and Thrombolysis in Myocardial Infarction (TIMI) in identifying low-risk acute coronary syndrome (ACS) patients and predicting 30-day major adverse cardiac events (MACE).

Materials and Methods: This prospective study included patients aged ≥18 years with nontraumatic chest pain evaluated for ACS. HEART, TIMI, EDACS, and EDACS-ADP scores were calculated. MACE, including myocardial infarction, urgent revascularization, or death, was determined via telephone follow-up. Diagnostic performance was assessed using area under the curve (AUC) analysis.

Results: Among 408 patients, 64 (15.7%) developed MACE. The HEART score had the highest AUC (0.823), followed by TIMI (0.784), EDACS-ADP (0.769), and EDACS (0.716). HEART had the highest sensitivity (90.6%) and negative predictive value (NPV; 97.2%). TIMI, at a ≤1 cut-off, had sensitivity of 81.3% and NPV of 94.7%; reducing the cut-off to <1 increased sensitivity to 96.8% and NPV to 98.8%. EDACS showed sensitivity of 56.2% and NPV of 90.3%, whereas EDACS-ADP had sensitivity of 82.8% and NPV of 95.7%.

Conclusion: The HEART score outperformed TIMI, EDACS, and EDACS-ADP in predicting 30-day MACE, with superior sensitivity and NPV. Adjusting the TIMI cut-off enhances diagnostic performance but may increase ED stay. The HEART score is the most reliable tool for identifying low-risk patients with ACS and enabling safe discharge.

Keywords:. Acute Coronary Syndrome, Chest pain, EDACS, HEART, MACE, TIMI

Öz

Amaç: Bu çalışma, Emergency Department Assessment of Chest Pain Score (EDACS), History, Electrocardiography, Age, Risk Factors, Troponin (HEART) ve Thrombolysis in Myocardial Infarction (TIMI) skorlarının düşük riskli akut koroner sendrom (AKS), hastalarını belirleme ve 30 günlük majör istenmeyen kardiyak olayları (MİKO) öngörme performanslarını karşılaştırmayı amaçlamıştır.

Gereç ve Yöntem: Bu prospektif çalışmaya, travmatik olmayan göğüs ağrısı ile AS'ye başvuran ve AKS açısından değerlendirilen 18 yaş ve üzeri hastalar dahil edilmiştir. HEART, TIMI, EDACS ve EDACS-ADP skorları hesaplanmıştır. Miyokard enfarktüsü, acil revaskülarizasyon veya ölüm MİKO olarak tanımlanmış ve telefonla takip yoluyla doğrulanmıştır. Tanısal performans, eğri altındaki alan (EAA) analizleri ile değerlendirilmiştir.

Bulgular: Çalışmaya 408 hasta dahil edilmiş ve 64'ünde (%15.7) MİKO gelişmiştir. En yüksek EAA değeri HEART skoruna (0,823) aitken, bunu TIMI (0,784), EDACS-ADP (0,769) ve EDACS (0,716) takip etmiştir. HEART, en yüksek duyarlılık (%90,6) ve negatif prediktif değer (NPD, %97,2) göstermiştir. TIMI'nin ≤1 kesim değerinde duyarlılık %81,3 ve NPD %94,7 iken, kesim değerinin <1'e düşürülmesi duyarlılığı %96,8 ve NPD'yi %98,8'e çıkarmıştır. EDACS, %56,2 duyarlılık ve %90,3 NPD gösterirken, EDACS-ADP %82,8 duyarlılık ve %95,7 NPD göstermiştir.

Sonuç: HEART skoru, 30 günlük MİKO'yu öngörmede TIMI, EDACS ve EDACS-ADP'den üstün performans göstermiş, en iyi duyarlılık ve NPD'ye sahip olmuştur. TIMI kesim değerinin ayarlanması tanısal performansı artırabilir, ancak AS'de kalış süresini uzatabilir. HEART skoru, düşük riskli AKS hastalarını belirlemek ve güvenli taburculuk kararlarını desteklemek için en güvenilir araçtır.

Anahtar kelimeler: Akut koroner sendrom, EDACS, HEART, Göğüs ağrısı, MİKO, TIMI

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INTRODUCTION

Chest pain is one of the most common symptoms in the emergency department (ED)[1]. It can be caused by pathologies arising from the cardiovascular, pulmonary, gastrointestinal, neurological, and musculoskeletal systems[2]. Although chest pain in the majority of patients presenting to the ED is non-cardiac in origin, acute coronary syndrome (ACS) should be considered because it is one of the leading causes of death worldwide and the most common serious etiology of chest pain[3, 4].

ACS refers to a group of diseases characterized by myocardial ischemia. The diagnosis of ACS is based on patient history, electrocardiography (ECG) findings, cardiac biomarkers, and several other potential variables. Nonetheless, biomarkers within normal limits and normal ECG tracing do not definitively indicate that the patient does not have ACS. Approximately 2%–6% of patients with ACS are reportedly missed. This difficulty in diagnosing ACS is associated with prolonged ED stay, unnecessary investigations, and increased frequency of hospitalizations, resulting in increased costs. International guidelines recommend using risk-scoring tools because of their superiority over clinical assessment and their benefits[5–9]. These risk scoring tools include scores such as History, ECG, Age, Risk Factors, Troponin (HEART), Thrombolysis in Myocardial Infarction (TIMI), Global Registry of Acute Coronary Events (GRACE), and the Emergency Department Assessment of Chest Pain Score (EDACS)[10–12].

The HEART score was developed to identify patients at low risk for the development of major adverse cardiac events (MACE) and is based on five parameters: history, ECG, age, risk factors, and troponin levels[13]. The TIMI score was derived from data on patients with known unstable angina pectoris (USAP), and non-ST-elevation myocardial infarction and comprises seven parameters[14]. The EDACS was designed specifically for ED use, utilizing clinical data to identify patients at low risk for 30-day MACE. It consists of four categories: age, gender, risk factors, and symptoms/signs[15]. The EDACS – Accelerated Diagnostic Protocol (EDACS-ADP) is an accelerated diagnostic protocol that includes the EDACS score, cardiac troponin levels, and ECG findings[1,16]. The EDACS-ADP was developed to identify patients with an extremely low short-term risk of MACE who can be safely discharged from the ED[16].

Studies that have directly compared the performance of risk scores in the same patient population presenting with chest pain have reported inconsistent results regarding the ideal scoring system to be used in the ED. Moreover, it is unclear which scoring system is the best for predicting low risk of ACS in patients in the ED[5,10]. This uncertainty underscores the need for a comparison of these tools to determine their effectiveness in identifying patients with low ACS risk and predicting short-term adverse outcomes. A systematic comparison of commonly used scores, including HEART, TIMI, EDACS, and EDACS-ADP, is crucial to identifying the most reliable tool for safely discharging patients and optimizing ED workflow. This study aimed to address this gap by evaluating the diagnostic accuracy of these risk scores in identifying low-risk ACS patients and predicting 30-day MACE.

MATERIALS AND METHODS

Sample

This study is a single-center, prospective cohort study and was conducted between January 1, 2022, and May 1, 2022, in the Department of Emergency Medicine of Ordu University Training and Research Hospital, after the approval of the Ordu University Clinical Research Ethics Committee (No: 2021/211; date of approval: September 23, 2021). The Department of Emergency Medicine at the Ordu University Training and Research Hospital is a 3rd level ED of a health institution with approximately 100 000 admissions per year. Individuals aged ≥18 years who presented to the ED with nontraumatic chest pain and in whom a troponin assay was ordered by the attending physician due to suspicion of ACS were included in the study. The participants were included only after they provided written informed consent. Participants who were <18 years of age, were pregnant, had a history of trauma, demonstrated ST-segment elevation on ECG, or exhibited signs of chest pain due to etiologies other than ischemic heart disease were excluded from the study. Additionally, patients who had previously participated in the study, who withdrew their consent, and whose data were missing or could not be accessed during follow-up were excluded from the study.

In the literature, studies comparing the performance of risk scores have shown that the sensitivity differences between HEART and TIMI scores range from 5.7% to 19.5%. Similarly, the sensitivity

differences between HEART and EDACS range from 4.2% to 18.5%[10,11,18,19]. In the present study, when calculating the sample size required to detect a 5% sensitivity difference between scores (Score 1: %95 sensitivity and Score 2: %90 sensitivity) with 0.80 power and a 0.05 Type I error rate, the sample size was determined to be 159 patients at the point of minimum disagreement between the two tests, including a 10% correction rate. At the point of maximum disagreement, the required sample size was calculated to be at least 357 patients with a 10% correction rate[20].

Procedure

The patient data was recorded by the physician, who first evaluated the patient through a predetermined data collection form. Beforehand, a meeting was held with all emergency physicians involved in patient care about the data collection method. ECG was performed within the first 10 minutes of presentation to the ED with chest pain, and patients with ST-segment elevation were excluded from the study. After the initial evaluation of the patients, the following data were collected: age, sex, height and weight, telephone number, family history, personal history, medication use, clinical characteristics, ECG characteristics, and cardiac troponin values. Family history was considered positive if a first-degree relative had a history of cardiovascular disease or cardiac-related death before the age of 55 years. The ECGs were classified as normal, having repolarization abnormalities, and demonstrating significant ST-segment depression. Bundle branch block, left ventricular hypertrophy, digoxin use, and implanted right ventricular pacemaker rhythm were considered as repolarization abnormalities. ST-segment depression of >0.5 mm in at least two adjacent leads was considered a significant ST-segment depression.

Table 1. HEART score calculation

Parameters		**Score**
History	Slightly suspicious	0 point
	Moderate suspicious	1 point
	Highly suspicious	2 points
ECG	Normal ECG	0 point
	Non-specific repolarization disturbance *	1 point
	Significant ST depression†	2 points
Age	<45 years	0 point
	45-64 years	1 point
	≥65 years	2 points
Risk Factors**	No known risk factors	0 points
	1-2 risk factors	1 point
	≥3 risk factors or history of atherosclerotic disease††	2 points
Troponin***	≤ normal limit	0 points
	1-3x normal limit	1 point
	≥3x normal limit	2 points
Low suspicion; Absence of symptoms of ischemic chest pain Moderate suspicion; Coexistence of typical and atypical chest pain symptoms High suspicion; Presence of typical ischemic chest pain symptoms * Bundle branch block, left ventricular hypertrophy, digoxin use, implanted right ventricular pacemaker † Significant ST-segment deviation without LBBB, LVH, or digoxin use. ** Hypertension, dyslipidemia, diabetes, obesity (BMI >30 kg/m²), smoking (current, or smoking cessation ≤3 mount), positive family history (parent or sibling with CAD before age 55). †† Prior MI, PCI/CABG, CVD/TIA, or peripheral arterial disease *** Use local, regular sensitivity troponin assays and corresponding cutoffs.		
Classification: 0-3 points low risk, 4-6 points intermediate risk, ≥7 points high risk		

BMI: Body mass index, ECG: Electrocardiography, CAD: Coronary artery disease, CABG: Coronary artery bypass grafting, CVD: Cerebrovascular disease, HEART: History electrocardiography age risk factors troponin, LBBB: Left bundle branch block, LVH: Left ventricular hypertrophy, MI: Myocardial infarction, PCI: Percutaneous coronary intervention, TIA: Transient ischemic attack.

Table 2. TIMI score calculation

Parameters	Score
Age ≥ 65	1 point
≥ 3 Coronary artery disease risk factors*	1 point
Known coronary artery disease (stenosis ≥50%)	1 point
ASA use in past 7 days	1 point
Severe angina (≥2 episodes in 24 hrs)	1 point
ECG ST changes ≥0.5mm	1 point
Positive cardiac marker	1 point
*Risk Factors: Hypertension, dyslipidemia, diabetes, family history of coronary artery disease, or current smoker	
Classification: TIMI Score ≤1 low risk, TIMI Score >2 high risk	

ASA: Acetylsalicylic acid, ECG: Electrocardiography, TIMI: Thrombolysis in myocardial infarction.

Table 3. EDACS Calculation

Variable	Score
Age;	
18-45	+2 points
46-50	+4 points
51-55	+6 points
56-60	+8 points
61-65	+10 points
66-70	+12 points
71-75	+14 points
76-80	+16 points
81-85	+18 points
≥86	+20 points
Sex;	
Male	+4 points
Risk Factors (18-50 years)* • Known coronary artery disease† or • ≥3 risk factors**	+4 points
Symptoms and Signs;	
Diaphoresis	+3 points
Pain radiates to arm, shoulder, neck, or jaw	+5 points
Pain occurred or worsened with inspiration	-4 points
Pain is reproduced by palpation	-6 points
* Risk factors should only be evaluated in patients between the ages of 18 and 50. † Known coronary artery disease: previous acute myocardial infarction, coronary artery bypass graft, or percutaneous intervention. ** Risk Factors: Hypertension, dyslipidemia, diabetes, family history of premature coronary artery disease, or current smoker.	
Classification: <16 points low risk, ≥16 points high risk	

EDACS: Emergency department assessment of chest pain score.

A high-sensitivity troponin test was not performed in the present study. Troponin was measured using Elecsys Reagent Troponin I STAT assay via Cobas 6000 analyzer (Roche Diagnostics, Basel, Switzerland). Cardiac troponin levels were evaluated based on the limits determined by the hospital biochemistry laboratory and classified as normal, 1–3 times the normal limit, or >3 times the normal limit. Additionally, troponin values within the normal limits were considered negative, whereas those above the normal limit were considered positive.

Calculation of HEART, TIMI, EDACS, and EDACS-ADP

The HEART, TIMI, EDACS, and EDACS-ADP scores were calculated separately for each patient. The parameters that constituted the scores were

considered separately. For the HEART score, 0–3 points were classified as low risk, 4–6 points as medium risk, and ≥7 points as high risk. In the EDACS score, <16 points were classified as low risk and ≥16 points as high risk. Studies in the literature demonstrate that when the cut-off value for the TIMI score is set at <1 point, it exhibits higher sensitivity and negative predictive value (NPV)[10,17]. Therefore, in this study, two different cut-off values were determined for the TIMI score to establish two separate risk classifications. First, patients with a TIMI score of 0–1 point were classified as low risk, while those with a score >1 points were classified as high risk. Second, patients with a TIMI score of 0 points were categorized as low-risk, whereas those with a score >0 points were categorized as high-risk. The calculation of the HEART, TIMI, and EDACS scores are presented in Tables 1, 2, and 3, respectively.According to the EDACS-ADP, patients with no new ischemic changes on ECG, normal troponin values at hours 0 and 2 of admission, and an EDACS score of <16 were classified as low risk[1,16]. Our study aimed to identify low-risk patients who presented to the ED with chest pain to reduce the length of their ED stay and safely discharge them without the need for further evaluation. Therefore, the EDACS-ADP was calculated using a single troponin level measured at admission. According to the EDACS-ADP used in this study, patients with no new ischemic changes on ECG, normal troponin values at the time of admission, and an EDACS score of <16 were classified as low-risk. The calculation for EDACS-ADP are presented in Table 4.

Table 4. EDACS-ADP Calculation

Classification
Low risk
• EDACS < 16
• ECG shows no new ischemia
• 0-hr troponin negative
High risk
• EDACS ≥ 16 or
• ECG shows new ischemia or
• 0-hr troponin positive

ECG: Electrocardiography, EDACS: Emergency department assessment of chest pain score, EDACS-ADP: Emergency department assessment of chest pain score - Accelerated Diagnostic Protocol.

Endpoints

Acute myocardial infarction (AMI), urgent need for revascularization such as percutaneous coronary intervention (PCI) and coronary artery bypass grafting (CABG), and death were considered as MACE. MACEs were recorded during the patient's first admission to the ED. Therefore, MACE was considered positive if it developed in patients who presented to the ED and were diagnosed with non-ST-elevation myocardial infarction after investigations and follow-up. The 30-day MACE development was determined using telephonic interviews and verified via the national health database after obtaining the patient consent.

The primary outcome was defined by comparing the performance of HEART, TIMI, and EDACS in predicting 30-day MACE development, while the secondary outcome was determined by comparing the performance of EDACS-ADP, obtained by adding ECG and cardiac troponin to the EDACS score, with existing risk scoring tools.

Statistical analysis

All statistical analyses were conducted using SPSS (version 26.0). The distribution of the variables was evaluated using histogram plots and the Kolmogorov–Smirnov test. Categorical variables were analyzed using the chi-square test, while the Student's t-test and Mann–Whitney U test were used for normally and non-normally distributed data, respectively. Variables were expressed as frequency and percentage or as median (25th and 75th percentiles). The relationship between MACE development and age was analyzed using the Mann–Whitney U test. Categorical data, including patient sex, medical history, clinical findings, symptoms, ECG findings, troponin levels, and categorized

versions of risk scores, were analyzed using the chi-square test. The diagnostic performance of the HEART, TIMI, EDACS, and EDACS-ADP scores in predicting 30-day MACE was assessed using receiver operating characteristic (ROC) curve analysis and the calculation of the area under the curve (AUC) with a 95% confidence interval (CI). The specificity, sensitivity, positive likelihood ratio (+LR), and negative likelihood ratio (-LR) of the scores were calculated with 95% CI using the Youden index. Statistical significance was set at $P < 0.05$.

RESULTS

Between January 1, 2022, and May 1, 2022, 439 patients who were admitted to the ED with chest pain were evaluated. Eleven of these patients had missing data, three had recurrent admissions, and 17 had chest pain due to non-ischemic heart disease. Finally, 31 patients were excluded and 408 patients were included in the study (Figure 1).

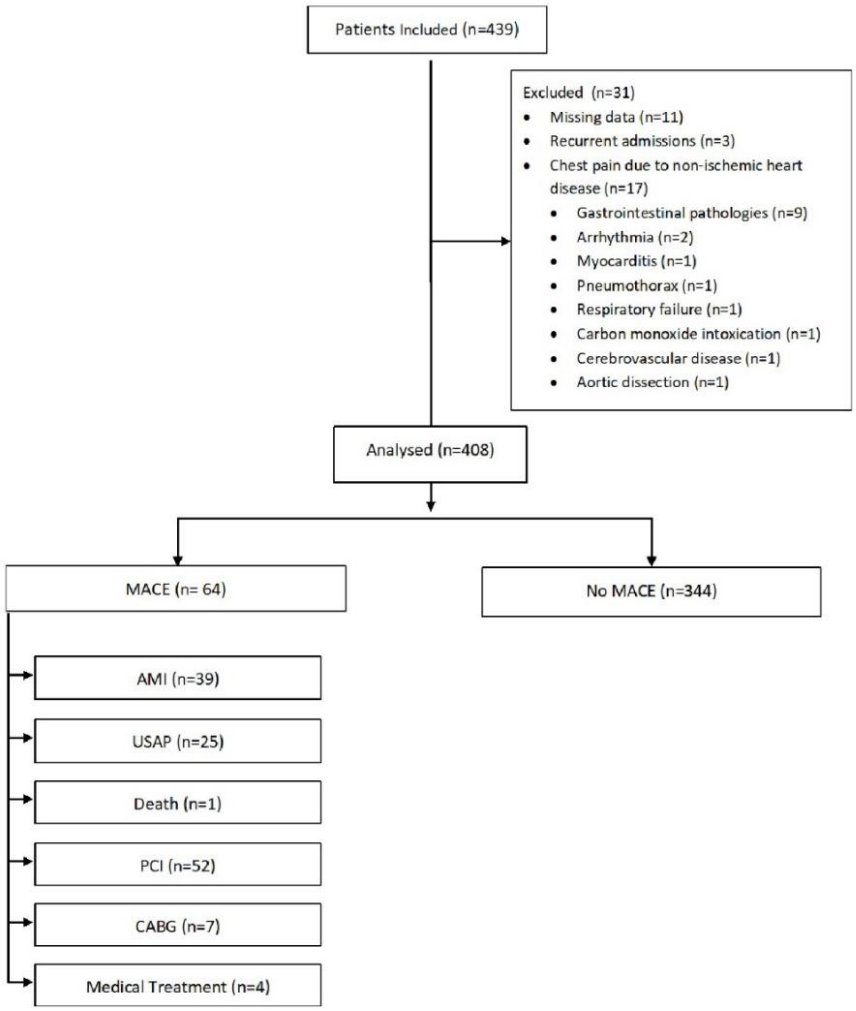

Figure 1. The study flowchart and primary outcomes.

Among 408 patients, 61.5% were male and 38.5% were female. The mean age of the study participants was 50.4±16.21 years (range: 18–92 years). There was no significant difference in sex distribution between patients with and without MACE (p = 0.917). History of diabetes, hypertension, dyslipidemia, coronary artery disease, PCI, CABG, >50% coronary artery stenosis, and aspirin use in the last seven days were significantly associated with MACE (p < 0.001). There was also a statistically significant association between a history of obesity and the development of MACE (p = 0.007). Furthermore, the spread of pain to the shoulder, neck, or jaw (p < 0.001) and an angina attack in the last 24 hours (p < 0.007) were significantly associated with the development of MACE. The statistical relationships between MACE development and the risk factors, demographic and background characteristics of the patients, prior history, ECG findings, and troponin levels are illustrated in Tables 5, 6, and 7.

Table 5. Demographic and history characteristics of the patients and risk factors

		MACE		p
		No (n=344)	**Yes (n=64)**	
Age		48.50 (37-60)	60 (50-70.75)	**<0.001**
Gender	Female	132 (84.1%)	25 (15.9%)	0.917
	Male	212 (84.5%)	39 (15.5%)	
Family history of cardiovascular disease	No	260 (84.4%)	48 (15.6%)	0.921
	Yes	84 (84%)	16 (16.0%)	
History of hypertension	No	180 (92.8%)	14 (7.2%)	**<0.001**
	Yes	164 (76.6%)	50 (23.4%)	
History of diabetes	No	284 (87.9%)	39 (12.1%)	**<0.001**
	Yes	60 (70.6%)	25 (29.4%)	
History of obesity	No	298 (86.4%)	47 (13.6%)	**0.007**
	Yes	46 (73.0%)	17 (27.0%)	
History of dyslipidemia	No	275 (90.5%)	29 (9.5%)	**<0.001**
	Yes	69 (66.3%)	35 (33.7%)	
History of CAD	No	265 (89.8%)	30 (10.2%)	**<0.001**
	Yes	79 (69.9%)	34 (30.1%)	
History of CABG	No	336 (86.9%)	51 (13.1%)	**<0.001**
	Yes	7 (35.0%)	13 (65.0%)	
History of PCI	No	255 (89.5%)	30 (10.5%)	**<0.001**
	Yes	89 (72.4%)	34 (27.6%)	
History of PAD	No	330 (84.6%)	60 (15.4%)	0.457
	Yes	14 (77.8%)	4 (22.2%)	
CVD history (including TIA)	No	334 (84.6%)	61 (15.4%)	0.480
	Yes	10 (76.9%)	3 (23.1%)	
History of tobacco use	No	189 (83.3%)	38 (16.7%)	0.512
	Yes	155 (85.6%)	26 (14.4%)	
History of >50% coronary artery stenosis	No	274 (89.5%)	32 (10.5%)	**<0.001**
	Yes	70 (68.8%)	32 (31.4%)	
Aspirin use in the last 7 days	No	241 (89.6%)	28 (10.4%)	**<0.001**
	Yes	103 (74.1%)	36 (25.9%)	
Number of risk factors	No risk factors	56 (96.6%)	2 (3.4%)	**<0.001**
	1-2 risk factors	161 (92.5%)	13 (7.5%)	
	≥3 risk factors	127 (72.2%)	49 (27.8%)	

CAD: Coronary artery disease, CABG: Coronary artery bypass graft, CVD: Cerebrovascular disease, ECG: Electrocardiography, MACE: Major adverse cardiac events, PAD: Peripheral artery disease, PCI: Percutaneous coronary intervention, TIA: Transient ischemic attack

Table 6. Clinical features and symptoms of patients

		MACE		p
		No (n=344)	Yes (n=64)	
Characteristics of the history	Low suspicion*	97 (98.0%)	2 (2.0%)	**<0.001**
	Moderate suspicion**	175 (85.0%)	31 (15.0%)	
	High suspicion***	72 (69.6%)	31 (30.4%)	
Radiate of pain to the shoulder, neck or jaw	No	174 (91.1%)	17 (8.9%)	**<0.001**
	Yes	170 (78.3%)	47 (21.7%)	
Diaphoresis	No	246 (86.6%)	38 (13.4%)	0.053
	Yes	98 (79.0%)	26 (21.0%)	
Pain occurred or worsened with inspiration	No	206 (85.1%)	36 (14.9%)	0.587
	Yes	138 (83.1%)	28 (16.9%)	
Pain is reproduced by palpation	No	281 (83.9%)	54 (16.1%)	0.606
	Yes	63 (86.3%)	10 (13.7%)	
At least 2 angina attacks in the last 24 hours	No	237 (87.8%)	33 (12.2%)	**0.007**
	Yes	107 (77.5%)	31 (22.5%)	

*Low suspicion; Absence of symptoms of ischemic chest pain
**Moderate suspicion; Coexistence of typical and atypical chest pain symptoms
***High suspicion; Presence of typical ischemic chest pain symptoms
MACE: Major adverse events

Table 7. ECG findings and troponin values of patients

		MACE		p
		No (n=344)	Yes (n=64)	
ECG characteristics	Normal ECG	280 (88.9%)	35 (11.1%)	**<0.001**
	Repolarization disorders	49 (75.4%)	16 (24.6%)	
	ST segment depression	15 (53.6%)	13 (46.4%)	
Troponin levels	Normal limit	344 (88.9%)	43 (11.1%)	**<0.001**
	1-3 x normal limit	0 (0.0%)	6 (100.0%)	
	≥ 3 normal limit	0 (0.0%)	15 (100.0%)	

ECG: Electrocardiography, MACE: Major adverse cardiac events.

Outcomes

Of the 408 patients, 64 (15.7%) developed MACE, 39 (60.9%) were diagnosed with AMI, and 25 (39.1%) were diagnosed with USAP. Among the patients with MACE, 52 (81.2%) underwent PCI, seven (10.9%) underwent CABG, four (6.3%) were managed conservatively, and one (1.6%) died during follow-up.

Characteristics of the HEART, TIMI, EDACS, and EDACS-ADP

Based on the HEART score, the rates of MACE in the low-, medium-, and high-risk groups were 2.8%, 23.9%, and 62.5%, respectively. Based on the TIMI score, the rates of MACE in the low- and high-risk groups were 5.3% and 28.4%, respectively. Based on the EDACS, the rates of MACE in the low- and high-risk groups were 9.7% and 30%, respectively. Based on the EDACS-ADP score, the rates of MACE development in the low- and high-risk groups were 4.4% and 35.3%, respectively (Table 8).

When the ROC curves of the three scores (Figure 2) for predicting the 30-day MACE in patients admitted to the ED with chest pain were compared, the AUCs for the HEART, TIMI, EDACS, and EDACS-ADP scores were 0.823 (95% CI, 0.775–0.871), 0.784 (95% CI, 0.728–0.840), 0.716 (95% CI, 0.653–0.779), and 0.769 (95% CI, 0.708-0.830) respectively (Table 9). These findings were statistically significant ($p < 0.001$). The cut-off values, sensitivity, specificity, positive predictive value, NPV, +LR, -LR, and accuracy values of the HEART, TIMI, EDACS, and EDACS-ADP are listed in Table 10.

Table 8. Relationship between risk groups of HEART, TIMI, EDACS and EDACS-ADP scores and MACE development.

		MACE		p
		No (n=344)	Yes(n=64)	
HEART score	0-3 points (low risk)	211 (97.2%)	6 (2.8%)	**<0.001**
	4-6 points (moderate risk)	121 (76.1%)	38 (23.9%)	
	≥7 points (high risk)	12 (37.5%)	20 (62.5%)	
TIMI score	0-1 points (low risk)	213 (94.7%)	12 (5.3%)	**<0.001**
	≥ 2 points (high risk)	131 (71.6%)	52 (28.4%)	
TIMI score	0 points (low risk)	130 (98.5%)	2 (1.5%)	**<0.001**
	> 0 points (high risk)	214 (77.5%)	62 (22.5%)	
EDACS	0-15 points (low risk)	260 (90.3%)	28 (9.7%)	**<0.001**
	≥ 16 points (high risk)	84 (70.0%)	36 (30.0%)	
EDACS-ADP	Low risk	241 (95.6%)	11 (4.4%)	**<0.001**
	High risk	97 (64.7%)	53 (35.3%)	

EDACS: Emergency department assessment of chest pain score, EDACS-ADP: Emergency department assessment of chest pain score - Accelerated Diagnostic Protocol, HEART: History electrocardiography age risk factors troponin, MACE: Major adverse cardiac events, TIMI: Thrombolysis in myocardial infarction.

Table 9. ROC analysis of HEART, TIMI and EDACS scores in predicting 30-day MACE.

Risk Scores	AUC	%95 CI	SE	P
HEART score	0.823	0.775-0.871	0.025	**<0.001**
TIMI score	0.784	0.728-0.840	0.029	**<0.001**
EDACS	0.716	0.653-0.779	0.032	**<0.001**
EDACS-ADP	0.769	0.708-0.830	0.031	**<0.001**

AUC: Areas under the curve, CI: Confidence interval, EDACS: Emergency department assessment of chest pain score, EDACS-ADP: Emergency department assessment of chest pain score- Accelerated diagnostic protocol, HEART: History electrocardiography age risk factors troponin, MACE: Major adverse cardiac events, ROC: receiver operating characteristics, SE: Standard error, TIMI: Thrombolysis in myocardial infarction.

Table 10. Characteristics of the performance of HEART, TIMI, EDACS, and EDACS-ADP.

	Cut-off Point	Sensitivity	Specifity	PPV	NPV	+LR	-LR	ACC
HEART	≤3	0.906 (0.807-0.965)	0.613 (0.560-0.665)	0.304 (0.239-0.374)	0.972 (0.941-0.990)	2.344 (2.008-2.736)	0.143 (0.071-0.329)	0.659 (0.613-0.705)
TIMI	<1	0.968 (0.891-0.996)	0.377 (0.326-0.431)	0.224 (0.208-0.241)	0.984 (0.942-0.996)	1.56 (1.42-1ç71)	0.08 (0.02-0.33)	0.470 (0.421-0.520)
TIMI	≤1	0.813 (0.695-0.899)	0.619 (0.566-0.671)	0.284 (0.220-0.355)	0.947 (0.909-0.972)	2.134 (1.784-2.552)	0.303 (0.181-0.508)	0.650 (0.603-0.696)
EDACS	>16	0.562 (0.433-0.686)	0.756 (0.707-0.800)	0.300 (0.220-0.390)	0.903 (0.863-0.934)	2.304 (1.732-3.063)	0.579 (0.436-0.769)	0.725 (0.682-0.769)
EDACS-ADP	Low risk / High risk	0.828 (0.713-0.911)	0.709 (0.658-0.757)	0.346 (0.271-0.427)	0.957 (0.924-0.978)	2.849 (2.334-3.477)	0.242 (0.141-0.417)	0.728 (0.685-0.771)

ACC: Accuracy, EDACS: Emergency department assessment of chest pain score, EDACS-ADP: Emergency department assessment of chest pain score - accelerated diagnostic protocol, HEART: History electrocardiography age risk factors troponin, +LR: Positive likelihood ratio, -LR: Negative likelihood ratio, MACE: Major adverse cardiac events, PPV: Positive predictive value, NPV: Negative predictive value.

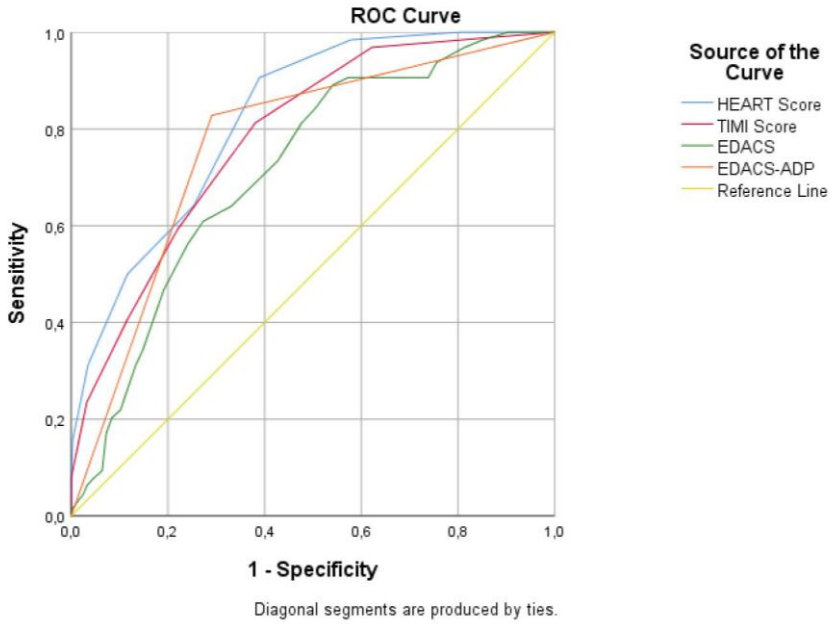

Figure 2. ROC curves of HEART, TIMI, EDACS and EDACS-ADP scores for 30-day MACE.

DISCUSSION

In this study, we aimed to compare the performance of HEART, TIMI, EDACS, and EDACS-ADP scores in predicting 30-day MACE in patients presenting to the ED with chest pain and identify patients with low-risk of ACS. We analyzed the ROC curves of the HEART, TIMI, EDACS, and EDACS-ADP scores, and their AUCs were 0.823 (95% CI, 0.775–0.871), 0.784 (95% CI, 0.728–0.840), 0.716 (95% CI, 0.653–0.779), and 0.769 (95% CI, 0.708-0.830) respectively. Our study results indicate that the HEART score was superior to the other scores in predicting 30-day MACE.

In this study, the HEART score demonstrated the best performance in predicting 30-day MACE, with an AUC value of 0.823, compared to other risk scores The HEART score was followed by the TIMI (AUC: 0.784), EDACS-ADP (AUC: 0.769), and EDACS (AUC: 0.716) scores. Moreover, the highest NPV in the study was observed for the HEART score at 97.2%. The NPVs of the TIMI, EDACS-ADP, and EDACS scores were 94.7%, 95.7%, and 90.3%, respectively. The findings of this study were consistent with those reported in the literature. In a study by Shin et al., the AUC values for the HEART, TIMI, and EDACS scores were reported as 0.765, 0.726, and 0.631, respectively. In the same study, the HEART score demonstrated the highest NPV at 94.3%, followed by the TIMI and EDACS scores at 91.2% and 88.9%[18]. Similarly, in a study by Wamala et al., the AUC values for the HEART, TIMI, and EDACS scores were reported as 0.82, 0.78, and 0.72, respectively. The NPV values in that study were 94% for HEART, 89% for TIMI, and 82% for EDACS[21]. These findings highlight that the HEART score provides superior discrimination and a higher NPV in identifying low-risk patients, which is consistent with previous studies in the literature.

In this study, the HEART score demonstrated superior performance (AUC, 0.823) compared to the TIMI, EDACS, and EDACS-ADP scores in predicting 30-day MACE. The HEART score exhibited good discriminatory power, although 2.8% of patients classified as low-risk still experienced MACE. The sensitivity and NPV of the HEART score were 90.6% and 97.2%, respectively. In the study conducted by Poldervaart et al., the sensitivity and NPV of the HEART score were reported as 96% and 98%, respectively, while Sakamoto et al. reported these values as 99.1% and 98%[9,10]. Both studies

yielded higher sensitivity and NPV values compared to the present study. A meta-analysis by Laureano-Phillips et al. revealed that the sensitivity of the HEART score increased when studies with a higher proportion of patients classified as low risk were excluded[22]. This finding aligns with the observations in this study, where the sensitivity of the HEART score may have been influenced by the composition of the study population. In terms of risk classification, 53.2% of patients in this study were identified as low risk according to the HEART score. This proportion is higher than the 39% reported by Poldervaart et al. and the 16.4% reported by Sakamoto et al.[9,10]. In contrast, the study by Leite et al. reported a similar finding, with 56.3% of patients classified as low risk[23]. These results indicate that a larger proportion of patients were classified as low risk in this study than in the studies by Sakamoto et al. and Poldervaart et al.[9,10]. Furthermore, Leite et al. reported sensitivity and NPV values of 90.1% and 97.9%, respectively, for the HEART score, which closely align with the findings of this study[23]. The relatively lower sensitivity observed in the present study compared to earlier investigations might be attributed to the higher proportion of patients classified as low-risk in this cohort. These findings emphasize the importance of considering population characteristics when interpreting the performance of the HEART score and highlight its robustness in stratifying risk, even in diverse clinical settings.

In this study, based on the TIMI score, 55.1% of the patients were in the low-risk group, with a cut-off value of ≤1. Additionally, MACE was observed in 5.3% of the patients in the low-risk group. For a TIMI cut-off score of ≤1, the sensitivity and NPV were 81.3% and 94.7%, respectively. Although opinions regarding the acceptable rates of MACE development in the low-risk group differ in the literature, NPV 98–99% is considered acceptable[1,5]. In this study, the NPV for the TIMI score was 94.7%. Therefore, to increase the sensitivity and NPV of the TIMI score, the cut-off point was reduced to <1. Subsequent analyses demonstrated a sensitivity and NPV of 96.87% and 98.78%, respectively. Furthermore, for a TIMI cut-off score of <1, MACE was observed in 1.52% of the patients in the low-risk group. The findings of the present study are similar to those of the previous studies[5,10]. In the study by Sakamoto et al., for a TIMI cut-off score of ≤1, the sensitivity and NPV were 87% and 83.9%, respectively. However, when the TIMI cut-off score was reduced to <1, the sensitivity and NPV were 97.2% and 91.2%, respectively[10]. Although fewer patients are missed when a TIMI cut-off score of <1 is considered than when a TIMI score of ≤ 1 is considered, it raises some concerns. In the present study, when a TIMI cut-off score of <1 was considered, fewer patients were classified as low-risk (55.1% vs. 32.4% for a cut-off of ≤1 vs. <1). This will result in more patients being further evaluated, and the length of ED stay being prolonged. In another study using a highly sensitive troponin test, when a TIMI cut-off score of ≤1 was considered, the sensitivity and NPV were 97% and 98.8%, respectively. These values are higher than those of the present study as well as those of Sakamato et al. Additionally, they determined that an NPV of 98.8% was acceptable, which is consistent with the findings of previous studies. However, a highly sensitive troponin test was not used in the present study or that by Sakamoto et al.[10,24]. These findings indicate that using a highly sensitive troponin test to calculate the TIMI score will demonstrate a better NPV without having to change the cut-off value.

In the present study, the sensitivity and NPV of the EDACS were 56.2% and 90.3%, respectively. Additionally, its performance was inferior to that of the HEART and TIMI scores. There are several possible reasons for this finding. First, EDACS includes more subjective parameters, such as the presence of chest pain or its worsening with inspiration, diaphoresis, and radiation of pain to the shoulder, neck or jaw, than the HEART and TIMI scores[1,18]. Although classical cardiac chest pain has been described in the literature, individuals from different cultures express their symptoms with different characteristics[25]. In the present study, pain that worsened with inspiration was present in 43.8% of patients who developed MACE. Additionally, we did not find a significant relationship between the development of MACE and the worsening of pain with inspiration ($p = 0.587$), diaphoresis ($p = 0.053$), or pain that could be reproduced by palpation ($p = 0.606$). Another reason for the poor performance of the EDACS is that the parameters do not include ECG findings and troponin values[1,16,19,26,27], which are important for the diagnosis of ACS[6,7]. In a study, the use of troponin as a marker for predicting ACS was more successful than the use of the EDACS alone[26].

Another aim of this study was to identify patients in the low-risk group at the time of admission so as to reduce the length of their ED stay and determine

whether they could be discharged safely without further assessment. Thus, we did not include the HEART pathway or EDACS-ADP diagnostic protocols, including serial troponin measurements[1]. We evaluated the EDACS-ADP score, calculated by combining a single troponin value measured at the time of admission with EDACS. Based on the EDACS-ADP score, 62.5% of the patients were classified as low-risk, and 4.4% of these patients developed MACE. Additionally, the sensitivity and NPV of the EDACS-ADP were 82.8% and 95.7%, respectively. In the study by Shin et al., the sensitivity and NPV of the EDACS-ADP score were 97.7% and 98.9%, respectively, whereas in the study by Stoprya et al., the sensitivity and NPV were 94.2% and 99%, respectively[1,16]. These findings indicated that the sensitivity of the EDACS-ADP score observed in the present study was lower than that reported in previous studies. The higher sensitivity and NPV values reported in studies evaluating the EDACS-ADP score[1,16,26] can be attributed to the inclusion of serial troponin measurements in these studies. In contrast, Body et al. reported a sensitivity of 96.2% and an NPV of 99.3% in a study using a single high-sensitivity troponin measurement with EDACS[19]. Considering these findings, the standard troponin test used in this study appears to have limited the sensitivity of the EDACS-ADP score. While it maintained a high NPV, it did not achieve sufficient reliability in identifying low-risk patients. The literature indicates that studies using high-sensitivity troponin tests demonstrate that a single measurement at the time of admission can achieve sensitivity and NPV levels comparable to those obtained with serial troponin measurements. The high sensitivity and NPV levels reported by Body et al. provide strong evidence for the effectiveness of this approach[19]. Therefore, based on the findings from previous studies, it can be suggested that using a single high-sensitivity troponin measurement might be a viable alternative to serial troponin measurements for identifying low-risk patients. However, it is important to emphasize that such a conclusion cannot be drawn based on the findings of the present study because of the troponin test and methodology employed. This study aimed to explore the potential reasons for the observed lower sensitivity and to provide a basis for investigating alternative testing strategies to enhance the effective use of EDACS-ADP.

This study has several important limitations. First, it was conducted in a single center with a smaller cohort of patients compared to previous similar studies[1,18,21]. This may have affected the performance of the risk scores. Additionally, the inclusion of patients from a single nation limits the generalizability of the findings. Individuals from different cultural backgrounds may express symptoms, such as chest pain, differently, which could influence clinical assessment processes[25]. In this context, it is essential to evaluate the findings of this study in a broader patient population. Multicenter and multinational studies could provide more comprehensive insights into the generalizability of these results and the impact of cultural differences on the performance of risk scores.

Second, this study did not use a high-sensitivity troponin test. High-sensitivity troponin tests improve the diagnostic accuracy for myocardial infarction compared with conventional tests and enable earlier diagnosis at the time of initial presentation[27,28]. These tests also provide prognostic information, potentially revealing that some patients classified as low-risk by conventional troponin tests may actually belong to the intermediate- or high-risk groups. The standard troponin test used in this study may have limited diagnostic accuracy, potentially leading to misclassification of risk levels in some patients. Furthermore, serial troponin measurements were not performed for all patients and the EDACS-ADP score was calculated using only a single troponin value measured at the time of admission. This approach may have resulted in reduced performance of the EDACS-ADP score and misclassification of some patients into the low-risk group.

Findings of this study provide a valuable foundation for evaluating the performance of risk scores based on a single troponin measurement. However, achieving higher sensitivity and NPV may require the use of high-sensitivity troponin tests. While this study was not designed to directly compare diagnostic protocols, it aimed to assess the potential of risk scores in reducing ED length of stay and facilitating safe discharge. Therefore, the impact of these limitations on the results must be acknowledged. Future multicenter studies with larger and more diverse populations are needed to further evaluate the performance of the EDACS-ADP and other scoring systems.

In the present study, the performance of the HEART score in predicting 30-day MACE was superior to that of the TIMI and EDACS scores. Although the development of MACE (2.8%) was less in low-risk patients classified based on the TIMI and EDACS, it

was below the acceptable rate for safe discharge. Therefore, the use of the HEART score for predicting 30-day MACE needs to be externally validated in future multinational studies involving a larger patient population. Additionally, assessing the scores using a high-sensitivity troponin test may improve the identification of low-risk patients.

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