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ORIGINAL RESEARCH

Determining whether A Low HEART Score Is Associated with Low Risk in Coronary Angiography Results: Validation of HEART Score Using Coronary Angiography Results

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Abstract

Purpose: The history, electrocardiogram, age, risk factor, and troponin (HEART) score have not yet been adopted in the emergency department (ED) in South Korea. We aimed to investigate whether patients with low HEART scores have a low risk of coronary angiography (CAG) results. **Methods:** Patients with chest pain with a possible cardiac etiology in the ED were included. Patients were divided into low-risk (0 – 3), intermediate-risk (4 – 6), and high-risk (7 – 9) groups according to the HEART score. We analysed the CAG results of the included patients. CAG results were divided into four grades: Grade I, $>$ 70%; Grade II, $>$ 50%; Grade III, 10% – 50%; and Grade IV, $<$ 10% of stenosis. The occurrence of a major adverse cardiac event (MACE) within 28 days was also investigated. **Results:** The study included 787 patients, of whom 458, 262, and 67 were included in the low-risk, intermediate-risk, and high-risk groups, respectively. A total of 118 cases of MACE occurred (average: 0.15 MACE/patient). MACE incidence was lower in the low-risk HEART score group than in the intermediate-risk and high-risk groups (0.4% vs. 22.1% and 86.6%, $p < 0.001$). The CAG results of the admitted patients with a low-risk HEART score were as follows: Grade I, 6.1%; Grade II, 3.0%; Grade III, 27.3%; and Grade IV, 63.6%. **Conclusions:** Patients with a low HEART score visiting the ED in Korea had a low risk in CAG results and a low probability of developing MACE. The successful utilization of the HEART score appears to be a rational approach that may avoid unnecessary testing in chest pain patients presenting to the ED.

Keywords

HEART score, Coronary angiography, Emergency department

1. Introduction

Patients complaining of chest pain are one of the common patient groups presenting to the emergency department (ED) for evaluation and admission [1, 2]. The evaluation of chest discomfort, tightness, and pain is frequently challenging for emergency physicians. However, chest pain can be caused by various medical problems, from muscle strain to a life-threatening myocardial infarction (MI), and typically, accurately diagnosing some form of an acute coronary syndrome (ACS) has diagnostic uncertainty [3].

The history, electrocardiogram (ECG), age, risk factors, and troponin (HEART) score, which consists of objective risk scores, was developed for risk stratification of patients with ACS-related symptoms and for identifying low-risk patients. who may not require objective cardiac testing in the acute setting.[4] Objective risk scores, such as history, ECG, age, risk factors, and troponin, are designed to help clinicians identify which patients require further hospital-based observation or testing and who can be safely discharged.

Unfortunately, the HEART score has not yet been adopted in the ED in Korea, and cardiologists tend to rely on numerous factors such as clinical experiences rather than objective risk scores such as the HEART score. Furthermore, the medical environment in Korea is different from that in other countries where previous studies of the HEART score have been conducted. Interestingly, coronary angiography (CAG) was performed more frequently for chest pain patients in Korea.

This study aimed to investigate whether low HEART score patients had a low risk in CAG results. We also validate the HEART score and its possibility as a disposition method in ED patients in Korea.

TABLE 1. The history, electrocardiogram, age, risk factors, and troponin (HEART) score for risk stratification of patients with ACS-related symptoms.

Component	Grade	Score
History (anamnesis)	Highly suspicious	2
	Moderately suspicious	1
	Slightly or non-suspicious	0
Electrocardiogram	Significant ST-depression	2
	Non-specific change	1
	Normal	0
Age	$\geq$ 65 years	2
	$>$ 45 – $<$ 65 years	1
	$\leq$ 45 years	0
Risk*	$\geq$ 3 risk factors, or history of atherosclerotic disease	2
	1 – 2 risk factors	1
	No risk factors known	0
Troponin	$\geq$ 3× normal limit	2
	$>$ 1 – $<$ 3 × normal limit	1
	$\leq$ Normal limit	0

ACS, acute coronary syndrome.
**Risk factors: hypertension, diabetes mellitus, hypercholesterolemia, smoker, family history, and obesity.*

2. Material and methods

2.1 Study design and setting

This retrospective, descriptive study was conducted at a tertiary referral and academic hospital in Seoul, Korea, which has an annual ED visit of approximately 70,000 patients. The medical records of patients who visited ED owing to sequential chest pain were retrospectively collected through chart reviews from January 2017 to December 2017.

The study was approved by the Internal Review Board (no. KUGH K2019-1395-001), and informed consent was waived by the board.

2.2 Selection of participants

We enrolled patients who initially visited the ED owing to chest pain and/or were admitted to the cardiology department via ED during the study period. Patients with chest pain, in which the diagnosis is uncertain, but the clinician considers a possible cardiac etiology, were included. Chest pain with possible cardiac etiology was defined as an acute chest, epigastric, neck, jaw, or left arm pain, or discomfort or pressure without an apparent non-cardiac origin.

Patients aged $<$ 18 years who were transferred to another institution or who died at the ED were excluded. Patients with evidence of definite ST-segment elevation MI (STEMI), high troponin T levels ($>$ 0.4 ng/mL) at initial presentation, or those who were clinically unstable, such as those who experienced shock, during the ED visit were also excluded. These patients should be treated in the usual manner and referred for ongoing medical management and/or revascularization.

2.3 Variables and data collection

Data on patient's age, sex, vital signs, medical and personal history (hypertension, diabetes, hyperlipidaemia, previous coronary artery disease, etc.), family history of coronary artery disease (CAD), laboratory results (including troponin T levels), and clinical outcomes were obtained from patients' medical records. ECG and measurement of troponin T levels were performed for all patients at ED presentation. Each patient's ECG was reviewed and classified as follows: ST-segment elevation/depression, T-wave inversion, flat T-wave, or no changes. STEMI was defined as a syndrome consisting of typical history, transient ST-segment elevations on consecutive 12-lead ECG, and an increase in troponin T levels.

Furthermore, CAG and percutaneous coronary intervention (PCI) results, cardiologist referral results, and cardiology unit admission rates were investigated. CAG and PCI were decided and performed by attending cardiologists. CAG results were divided into four grades, and the definition of each grade is as follows: Grade I, presence of $>$ 70% of stenosis in one of the three major arteries or in their first-order branches, which were eligible for PCI; Grade II, presence of $>$ 50% of stenosis in one of the three major coronary arteries or in their first-order branches; Grade III, presence of 10% – 50% of stenosis; and Grade IV, absence of CAD or presence of $<$ 10% of stenosis. PCI was defined as any therapeutic catheter intervention in the coronary arteries. major adverse cardiac event (MACE) and the final diagnosis of the enrolled patients were confirmed from hospital discharge records and outpatient unit medical records.

The HEART Score uses five components, assigned a score of 0, 1, or 2 points each (Table 1) [4]. The HEART score

TABLE 2. Baseline characteristics of the study participants.

	HEART score 0 – 3 (n = 458)	HEART score 4 – 6 (n = 262)	HEART score 7 – 9 (n = 67)
Age (years, mean ± SD)	48.6 ± 13.8	64.8 ± 11.7	68.1 ± 12.1
Male (n, %)	259 (56.6)	163 (62.2)	47 (69.1)
MAP (mmHg, mean ± SD)	100.5 ± 16.9	104.1 ± 18.2	104.5 ± 17.8
HR (bpm, mean ± SD)	79.1 ± 35.9	77.7 ± 14.8	96.0 ± 85.5
DM (n, %)	21 (4.6)	78 (29.8)	32 (47.8)
HTN (n, %)	107 (23.4)	170 (64.9)	49 (73.1)
Smoking (n, %)	68 (14.9)	58 (22.1)	18 (26.9)
Dyslipidemia (n, %)	27 (5.9)	35 (13.4)	14 (20.9)
Family history (n, %)	8 (1.8)	8 (3.1)	1 (1.5)
CAD history (n, %)	2 (0.5)	62 (23.7)	14 (20.9)
CAG history (n, %)	25 (5.5)	84 (32.1)	19 (28.4)
PCI history (n, %)	3 (0.7)	74 (28.2)	16 (23.9)
CABG history (n, %)	1 (0.2)	5 (1.9)	2 (3.0)
Stroke history (n, %)	1 (0.2)	18 (6.9)	7 (10.5)
Aspirin use (n, %)	26 (5.7)	99 (37.8)	24 (35.8)
Statin use (n, %)	15 (3.3)	76 (29.0)	23 (34.3)
Smoking (n, %)	68 (14.9)	58 (22.1)	18 (26.9)

SD, standard deviation; MAP, mean arterial pressure; HR, heart rate; DM, diabetes mellitus; HTN, hypertension; CAD, coronary artery disease; CAG, coronary angiography; PCI, percutaneous coronary intervention; CABG, coronary artery bypass graft.

was calculated based on the patient's history, ECG results, age, risk factors, and troponin T level. The troponin T value of the patient's first blood sample was used to calculate the HEART score. A combined score from 0 to 3 is considered low-risk for MACE.

Follow up data were retrieved from hospital records and any other relevant documentation. In a few cases where follow-up data were not available from hospital records, the patient or their guardian was called to obtain information on their condition, hospital admissions, myocardial infarction, revascularization, and medical data.

The charts were reviewed by two emergency physicians. When the chart reviewers were faced with conflicting data for categorical variables, a third investigator intervened in the chart reviewing process for such cases.

2.4 Study outcomes and analysis

Included patients were divided into low-risk (0 – 3), intermediate-risk (4 – 6), and high-risk (7 – 9) groups according to the HEART score for risk stratification [4]. The HEART score and patient distribution variables, including cardiologist referral and admission rates, CAG rates, and PCI rates, were compared among the groups. We analyzed CAG outcomes of the patients of low risk HEART score patients. We also investigated the occurrence of MACE within 28 days of the initial presentation to the ED. MACE is defined as myocardial infarction, coronary revascularization during index visit, or within 28 days, or cardiac cause mortality.

IBM SPSS software version 23 (released 2013, IBM Corp, Armonk, NY) was used for descriptive statistics and analysis comparing the means, frequencies, and proportions. Descriptive statistics were expressed as average ± standard deviation (SD). The differences between groups were assessed using a Student's t-test. Statistical significance was defined as a two-sided p value < 0.05.

3. Results

3.1 Baseline Characteristics

During the study period, a total of 1,022 patients visited the ED with a chief complaint of chest pain. Among them, 235 patients were excluded. A total of 787 patients were included in the study and were divided into three groups according to their HEART score: low-risk, intermediate-risk, and high-risk groups (Fig. 1). There were 458, 262, and 67 patients in the low-risk (0 – 3), intermediate-risk (4 – 6), and high-risk HEART score (7 – 9) groups, respectively. The baseline characteristics of the study population are represented in Table 2.

3.2 Clinical Outcomes of Enrolled Patients

Table 3 shows the clinical outcomes of enrolled patients with respect to the HEART score. Higher proportions of patients in the intermediate-risk and high-risk groups were referred to a cardiologist than those in the low-risk group (83.2% and 100% vs. 30.3%). Admission rates were much higher in the intermediate-risk and high-risk groups than in the low-risk group (45.8% and 100% vs. 8.1%). Overall, 2, 58, and 57 patients from the low-risk, intermediate-risk, and high-risk

TABLE 3. Clinical outcomes of the enrolled patients with respect to the HEART score.

	HEART score 0 – 3 (n = 458)	HEART score 4 – 6 (n = 262)	HEART score 7 – 9 (n = 67)
Consultation to cardiology (n, %)	139 (30.3)	218 (83.2)	67 (100)
Admission (n, %)	37 (8.1)	120 (45.8)	67 (100)
CAG (n, %)	33 (7.2)	113 (43.1)	59 (89.6)
PCI (n, %)	2 (0.4)	58 (22.1)	57 (85.1)
28-day mortality (n, %)	0 (0)	0 (0)	3 (4.5)
MACE (n, %)	2 (0.4)	58 (22.1)	58 (86.6)

CAG, coronary angiography; PCI, percutaneous coronary intervention; MACE, major adverse cardiac event.

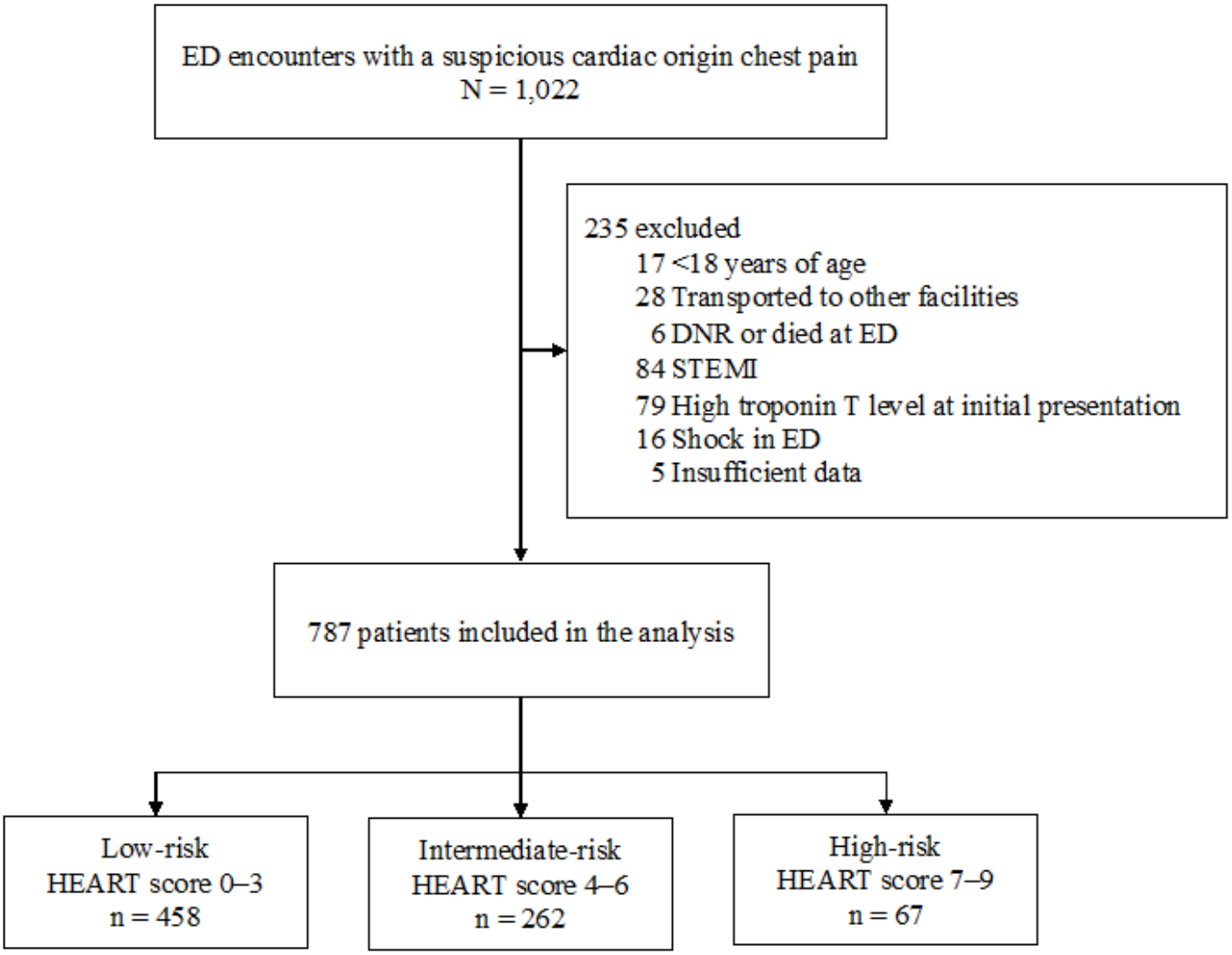


FIGURE 1. Flow diagram of patient enrolment in the study.
ED, emergency department; DNR, do not resuscitate; STEMI, ST-segment elevation myocardial infarction.

groups, respectively, underwent PCI (0.4% vs. 22.1%, 85.1%). Altogether, 118 cases of MACE occurred, with an average of 0.15 MACE/patient. The low-risk HEART score group had lower MACE incidence than the intermediate-risk and high-risk groups (0.4% vs. 22.1% and 86.6%). Of all included patients, three from the high-risk HEART group died. The average value of the HEART scores in groups with and without MACE are 6.39 ± 1.32 and 2.94 ± 1.40, respectively ($p < 0.001$). The C-statistic describing the accuracy of the HEART score in predicting MACE was 0.90 (95% confidence interval [CI]: 0.89 – 0.98). The sensitivity and specificity of the low-risk HEART score in predicting MACE were 98.3% (95% CI: 94.1 – 99.8%) and 68.2% (95% CI: 64.5 – 71.7%), respectively (Table 4).

3.3 CAG Results of the Admitted Patients Suspected of ACS

The CAG results of the admitted patients suspected of having ACS were as follows: low-risk HEART score group, Grade I:

TABLE 4. Diagnostic performance of the HEART score for predicting major adverse cardiac events.

HEART score	Sensitivity, % (95% CI)	Specificity, % (95% CI)	PPV, % (95% CI)	NPP, % (95% CI)	LR+ (95% CI)	LR− (95% CI)
Low (0–3)	98.3 (94.1–99.8)	68.2 (64.5–71.7)	35.3 (32.7–37.9)	99.6 (98.3–99.9)	3.09 (2.76–17.68)	0.02 (0.01–0.10)
High (7–9)	49.2 (39.8–58.5)	98.7 (97.5–99.4)	86.6 (76.7–92.7)	91.7 (90.2–92.9)	36.54 (18.61–71.71)	0.52 (0.43–0.62)

CI, confidence interval; PPV, positive predictive value; NPV, negative predictive value; LR+, positive likelihood ratios; LR-, negative likelihood ratios.

6.1%, Grade II: 3.0%, Grade: III 27.3%, and Grade IV: 63.6 %; intermediate-risk HEART score group, Grade I: 45.1%, Grade II: 18.6%, Grade III: 23.9%, and Grade IV: 12.4%; and high-risk HEART score group, Grade I: 91.7% and Grade II: 6.7% (Fig. 2).

4. Discussion

Our results demonstrated that the low HEART score represented a low risk in CAG results. The majority of ED patients with low-risk HEART score also had a low probability of developing MACE and could be safely discharged from the ED in Korea. However, two patients from the low-risk HEART score group underwent PCI. If a patient has persistent chest pain with a cardiac origin, it is necessary to perform complementary measures irrespective of the HEART score.

It is important to quickly detect ACS in ED patients with complaints of chest pain so that early treatment can be provided [3, 5]. In addition to clinical benefits, diagnostic strategies for chest pain can be helpful in relieving ED crowding, which is a growing problem and is associated with high mortality [6]. Therefore, clinicians in the ED must distinguish between more severe cases that require urgent treatment, and those that do not require urgent treatment. Because making the right clinical decision is crucial, to address these challenges, new diagnostic methods, including cardiac biomarkers, non-invasive stress testing or cardiac imaging, and risk scoring systems, have been developed to assist clinicians with risk assessment.

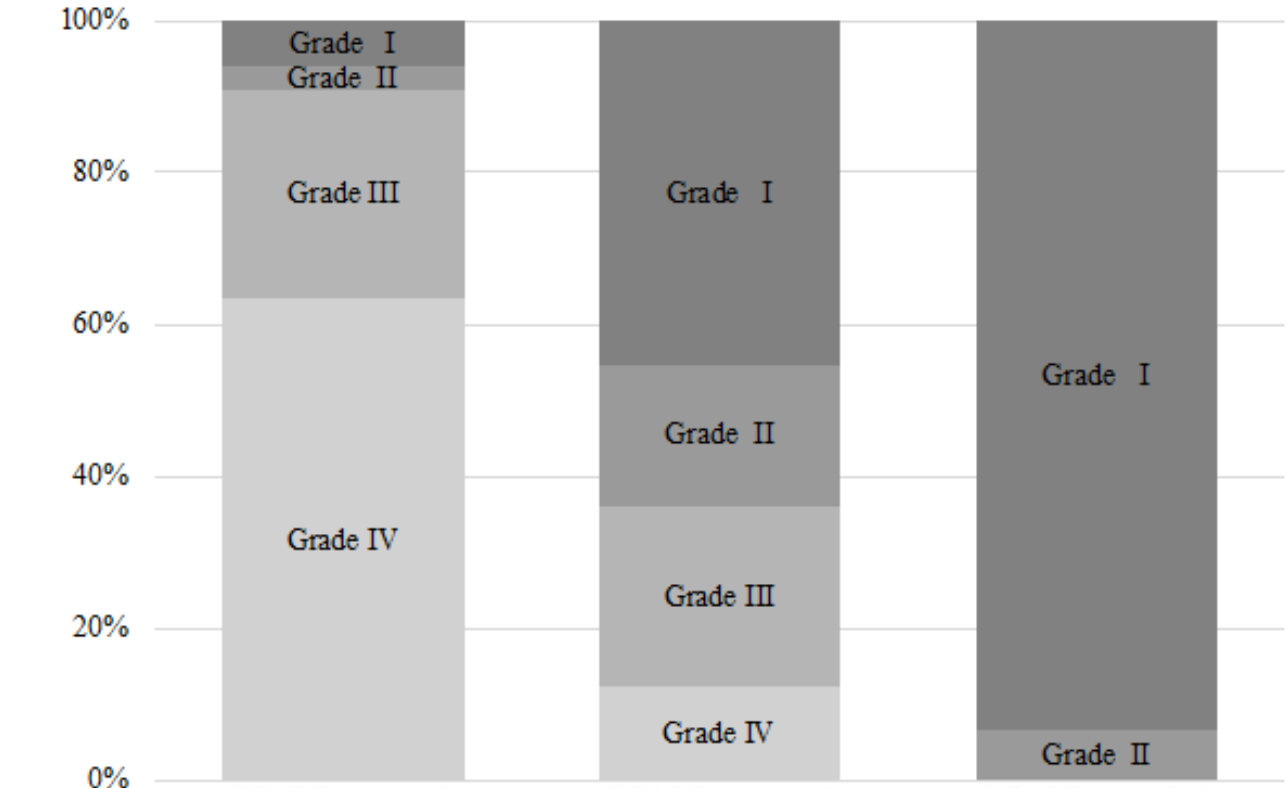
Serial cardiac biomarker testing in the ED, followed by outpatient objective cardiac testing, can be performed for low-risk patients as per the guidelines of the American College of Cardiology/American Heart Association [7, 8]. However, low-risk patients have low-risk rates for MACE, and the performance of serial cardiac biomarker testing or stress testing in all low-risk patients remains controversial. Moreover, referring low-risk patients to a cardiologist and hospitalization may lead to dissatisfaction, overtreatment, and additional expenditure [9]. Nevertheless, high-risk patients who have been misdiagnosed as low-risk patients may progress to MI and could be victims of out-of-hospital sudden cardiac death.

Several scoring systems such as Thrombolysis in Myocardial Infarction risk score, Global Registry of Acute Coronary Events risk score, and HEART score, have been used to help risk-stratify patients presenting with potential ACS [10]. Among them, the HEART score was developed for risk stratification of patients with ACS-related symptoms and for identifying low-risk patients who may not require objective cardiac testing in the acute setting. The HEART score has been proposed as a risk stratification tool with the potential to determine patients with very low risk and has been validated in several studies [11–15].

The utilization and benefit of the HEART score have been demonstrated in previous studies. Previous studies reported that low HEART score patients had a MACE rate of $< 0.9\%$ – 1.7%. In our study, similar to the results of other studies, the low-risk HEART score group had a low MACE rate (0.4%) and the absence of mortality (0%). However, 139 patients (30.3%) with low-risk HEART scores were referred to a cardiologist, while 37 (8.1%) were admitted. Among the 37 admitted patients from the low-risk HEART score group, 33 (7.2%) underwent CAG. Regardless of the significantly lower rate of MACE, compared with those from the intermediate-risk and high-risk groups, patients from the low-risk group were referred and admitted instead of discharging them from the ED. With a proper adaptation of the HEART score, unnecessary admissions and coronary angiography procedures could be decreased, and the affordability of care in Korea could improve.

Current guidelines recommend using structured risk stratification tools like HEART score to evaluate patients with suspected ACS presenting to the ED [16]. Nevertheless, some researchers argue that there is a limit to the performance of the HEART score to discharge low-risk patients and require attention to its application because patients with ACS-related symptoms can be undertriage or overtriage by HEART strategies [17, 18]. Therefore, it is necessary to perform complementary measures irrespective of the HEART score, or it is reasonable for low-risk patients to be discharged with close follow-up.

Two patients with low-risk HEART score underwent PCI in our study. The first patient was a 41-year-old man with a HEART score of 3. He experienced chest pain, which was described as feelings of heaviness and squeezing pain in the chest, with a visual analog scale (VAS) score of 6. Sublingual nitroglycerin (NTG) was administered three times, but the pain did not subside. ECG showed normal sinus rhythm, and the troponin level was within the normal range. CAG was performed. The left anterior descending coronary artery was partially occluded, while the proximal portion of the right circumflex coronary artery (RCA) was totally occluded. The second patient was a 61-year-old man with a HEART score of 3. He experienced chest pain, which was described as feelings of heaviness and squeezing pain in the chest, with a 20-minute VAS score of 6. After receiving sublingual NTG, the patient's



	HEART score 0–3	HEART score 4–6	HEART score 7–9
Grade I	2 (6.1%)	51 (45.1%)	55 (91.7%)
Grade II	1 (3.0%)	21 (18.6%)	4 (6.7%)
Grade III	9 (27.3%)	27 (23.9%)	0 (0%)
Grade IV	21 (63.6%)	14 (12.4%)	0 (0%)

FIGURE 2. Coronary angiography results of admitted patients suspected of acute coronary syndrome.
Grade 1: presence of > 70% of stenosis in one of the three major arteries or in their first-order branches.
Grade 2: presence of > 50% of stenosis in one of three major coronary arteries or in their first-order branches.
Grade 3: presence of 10% – 50% of stenosis. Grade 4: absence of coronary artery disease or presence of less < 10% of stenosis.

VAS score decreased to 2. Baseline ECG showed normal sinus rhythm. CAG was performed, which showed severe stenosis of the posterior left ventricular artery branch from the RCA.

These two patients underwent CAG procedure irrespective of the HEART score owing to clinical concerns regarding persistent and typical chest pain. If a 1% range of MACE rate remains a major concern for discharging chest pain patients safely, clinicians in the ED could consider performing additional measures (such as a repeated high-sensitive cardiac troponin) to assist in determining HEART score [19].

This study had some limitations. First, we conducted a descriptive analysis, with results similar to those of other studies. Nevertheless, our study has some advantages. It is unusual for low risk patients to undergo invasive cardiac evaluation, especially in western countries. CAGs were frequently conducted for chest pain patients with the active participation of cardiologists and were performed in our institution at a relatively modest cost because the test was covered by the national insurance system. We reviewed the CAG results to use as a comparative tool in analyzing HEART scores. Second, the study only used patients' data for one year, which were obtained from the medical records of a single hospital and may not be representative of all Korean hospitals, thereby reducing the generalizability of our findings. Third, this study may have some degree of selection bias because it included patients with cardiac origin chest pain at the emergency physician's discretion. It is possible that the excluded patients' data may have affected the results.

5. Conclusions

Our study showed that the patients with a low HEART score visiting the ED in Korea had low risk in CAG results and a low probability of developing MACE. The successful utilization of the HEART score in Korea appears to be a rational approach that may avoid unnecessary testing in chest pain patients presenting to the ED.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

DATA AVAILABILITY

The data used to support the findings of this study are available from the corresponding author upon request.

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