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BRIEF RESEARCH REPORT

Cardiology

Not all HEART scores are created equal: identifying "low-risk" patients at higher risk

Kimon L.H. Ioannides MD[1] | Benjamin C. Sun MD, MPP[2] | Aileen S. Baecker PhD[3] | Rita F. Redberg MD, MSc[4] | Ming-Sum Lee MD, PhD[5] | Maros Ferencik MD, PhD[6] | Yi-Lin Wu MS[3] | Ernest Shen PhD[3] | Chengyi Zheng PhD[3] | Visanee Musigdilok MPH[3] | Stacy J. Park PhD[3] | Adam L. Sharp MD, MS[3]

[1] National, Clinician Scholars Program, Department of Emergency Medicine, University of California, Los Angeles, Los Angeles, California, USA

[2] Department of Emergency Medicine and the Leonard Davis Institute of Health Economics, University of Pennsylvania, Philadelphia, Pennsylvania, USA

[3] Research and Evaluation Department, Kaiser Permanente Southern California, Pasadena, California, USA

[4] Division of Cardiology, University of California, San Francisco, San Francisco, California, USA

[5] Division of Cardiology, Los Angeles Medical CenterKaiser Permanente Southern California, Los Angeles, California, USA

[6] Knight Cardiovascular Institute, Oregon Health and Science University, Portland, Oregon, USA

Correspondence
Dr. Adam L. Sharp, MD, MS, Kaiser Permanente Department of Research and Evaluation, 100 S. Los Robles Ave. Pasadena, CA 91101, USA.
Email: adam.l.sharp@kp.org

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Abstract

Objective: We sought to identify sub-groups of "low-risk" HEART score patients (history, ECG, age, risk factors, and troponin) at elevated risk of acute myocardial infarction or death within 30 days.

Methods: We performed a secondary analysis of prospective emergency department (ED) encounters for suspected acute coronary syndrome in a large health system with low-risk HEART scores (0–5 points). Logistic regression using the 5 components of the HEART score analyzed the increase risk attributable to points from each of the 5 score components.

Results: Of 30,971 encounters among 28,992 unique patients, 135 (0.44%, 95% confidence interval [CI] = 0.37–0.51) experienced acute myocardial infarction or death. Risk increased for each component of the HEART score from 0 to 1 to 2 points (history, 0.4% to 0.5% to 0.6%; ECG, 0.3% to 0.7% to 0.7%; age, 0.2% to 0.3% to 0.7%; risk factors, 0.1% to 0.4% to 0.8%), except troponin, which had the highest risk with 1 point (troponin, 0.4% to 2.7% to 0.9%). Odds ratios from our regression, which adjusts for other components, showed a similar pattern (from 1 vs 0 and 2 vs 0 points, respectively: history, 1.0 and 1.8; ECG, 2.2 and 3.5; age, 1.2 and 2.1; risk factors, 2.4 and 4.2; and troponin, 6.0 and 3.6).

Conclusion: Among "low-risk" suspected acute coronary syndrome encounters, increasing points within each of the 5 categories demonstrated small increases in risk

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of death or acute myocardial infarction, with the troponin and ECG components representing the largest risk increases.

KEYWORDS
acute coronary syndrome, chest pain, coronary artery disease, HEART score, myocardial infarction

1 | INTRODUCTION

1.1 | Background

Acute coronary syndrome is both a leading cause of worldwide morbidity and mortality,[1] and symptoms suspicious for acute coronary syndrome are a common reason for emergency department (ED) visits associated with high health care costs.[2] The 5-component HEART score (H = history, E = electrocardiogram [ECG], A = age, R = risk factors, T = troponin, with each component graded from 0 to 2, for a total between 0 and 10) is recommended in American Heart Association guidelines to help risk stratify patients and is being increasingly used to assist in the evaluation of patients with suspected acute coronary syndrome.[3] Prior reports have demonstrated rates of 30-day death or acute myocardial infarction for patients evaluated in community EDs in the United States (US) to be below 1% for patients with HEART scores ≤5.[4]

1.2 | Importance

There is ample and growing evidence to support the accuracy and potential benefits of the HEART score, but it is unknown if subgroups of patients with the same HEART score may have different 30-day risks. For example, consider 2 patients reporting the same history of atypical chest pain: one patient is a 66-year-old with hypertension, but a normal troponin and ECG (with a corresponding HEART score consisting of history = 0 points, ECG = 0 points, age = 2 points, risk = 1 point, and troponin = 0 points, for a total of 3 points). The other patient is a 44-year-old with slightly elevated troponin and inferior ST-segment depression concerning for acute myocardial infarction, but no known risk factors (history = 0 points, ECG = 2 points, age = 0 points, risk = 0 points, troponin = 1 point, for a total of 3 points). Although both would receive the same total score and be recommended for discharge home in most pathways based on the HEART score, some might suggest the second patient is at substantially higher risk.

1.3 | Goals of this investigation

This study aims to evaluate the 5 components of the HEART score and identify subgroups of patients who might be at higher risk using a large ED patient population in the United States.

2 | METHODS

2.1 | Study design and setting

We analyzed a prospective sample of ED encounters among patients evaluated for suspected acute coronary syndrome among adults treated at 15 community hospitals in the Kaiser Permanente Southern California integrated health system, which together care for roughly 1 million ED patients per year, around 80% of whom are Kaiser Permanente Southern California health plan members, from May 20, 2016 to December 1, 2017. Implementation of a protocol for suspected acute coronary syndrome using the HEART score was previously studied in this population, and the present study examines a post-implementation period expanded from prior work by 6 months.[5] After any troponin result, mandatory, automated electronic decision support prompts collected history, ECG, and risk factor assessments from emergency physicians, who were expected to document a HEART score and encouraged to follow a recommended HEART clinical pathway.

2.2 | Selection of participants

We aimed to include all ED encounters for chest pain at potentially low-risk, starting with all adult Kaiser Permanente Southern California (≈80% of all ED visits) who had a documented HEART score, were not transferred to or from another hospital, and did not die in the ED. Encounters clearly not at low-risk were excluded, namely those with recognized "do not resuscitate" or hospice status (n = 2776), with a suspected acute myocardial infarction on the index ED visit (based on ICD-CM codes in the ED chart), with a troponin >0.50 ng/mL drawn before admission or discharge decision (n = 965), or with a HEART score of 6 or greater (n = 3744). Of note, admitted (or discharged) patients who, at any time other than the index ED visit (including during any hospitalization resulting from or following the index ED visit), were diagnosed with acute myocardial infarction or had an elevated troponin were still included. Analysis was repeated for the subset of patients with scores of 0 to 3, whom we call "very-low-risk" (these patients were generally recommended for discharge in the original HEART studies).

2.3 | Exposures

Components of the HEART score were assembled electronically from physician assessments, demographics, history, and the Beckman Coulter Access AccuTnI+3 troponin assay.

2.4 | Measurements

Additional demographic information and comorbidities were drawn from the electronic health record: cardiac risk factors such as hypertension and diabetes were defined using ICD and Elixhauser index codes; dyslipidemia, coronary artery disease, stroke, percutaneous coronary intervention (PCI), and coronary artery bypass graft (CABG) were similarly defined using ICD codes; body mass index (BMI) was measured from ED intake documentation or the most recently available visit; and finally, smoking and family history of coronary artery disease were extracted from self-reported fields in electronic health records. Education was proxied by the percentage of college-educated individuals at the census block level based on a patient's home zip code.

2.5 | Outcomes

The primary outcome was all-cause acute myocardial infarction or death within 30 days of the index visit, as assessed through in-network medical records, out-of-network claims data, and California and Social Security death files.

2.6 | Analysis

Generalized estimating equations for logistic regression (to account for repeated visits by the same patient) used solely the 5 components of the score to predict the primary outcome. From this regression, odds ratios were computed to estimate the increase in risk of death or acute myocardial infarction corresponding to incremental increases in each component of the HEART score. Because ECGs with significant ST deviation (ECG = 2 points) and troponin >3 times the normal limit (troponin = 2 points) were rare among these patients with "low-risk" HEART scores (0 to 5), a further sensitivity analysis combined the ECG = 1 or 2 points and troponin = 1 or 2 points components, respectively. Separately, rates of acute myocardial infarction or death were tabulated in subgroups based on each component of the HEART score. SAS version 9.4 (Cary, NC) was used for statistical analysis, and all confidence intervals (CI) are reported at the 95% level.

3 | RESULTS

3.1 | Characteristics of study subjects

We analyzed 30,971 ED encounters among 28,992 unique patients who met inclusion and exclusion criteria in this middle-aged ethnically diverse population (Table 1). Of these encounters, 135 (0.44%, CI 0.37, 0.52) experienced the primary outcome, acute myocardial infarction or death within 30 days (Table 1). The majority of encounters (19,757, 64%, among 18,950 unique patients) had very-low-risk scores (0 to 3), of whom 41 (0.21%, CI 0.15, 0.28) experienced the primary outcome. Among all included visits, those who had an acute myocardial infarction or died were older (mean age of 66.0 vs 58.7), more likely to be an active smoker (13.3% vs 6.9%), and much more likely to have comorbidities in the year prior such as coronary artery disease (30.4% vs 15.8%), diabetes (48.9% vs 29.0%), hypertension (75.6% vs 55.7%), lipid disorder (75.6% vs 60.9%), or stroke (10.4% vs 3.2%).

The Bottom Line

The HEART score is widely used to risk-stratify ED patients with chest pain. In 30,971 patient encounters, the authors sought to demonstrate whether individual components of the HEART score were associated with higher risk of death or myocardial infarction. They found that risk of death or MI increased with each added point, and that abnormal EKG and elevated troponin were associated with the largest increases in risk

3.2 | Main results

Table 2 and Figure 1 report the risk of acute myocardial infarction or death divided based on whether each component of the HEART score is 0, 1, or 2. The highest risk group had a troponin = 1 component, with a risk of 2.7% (CI = 1.7, 4.1). The ECG = 2 and troponin = 2 groups have small sample sizes and thus wide CIs. In the primary analysis, we found statistically significant increases in risk for ECG = 1, age = 2, risk = 1, risk = 2, and troponin = 1 versus the 0 points reference group. The troponin = 1 versus 0 points group showed the largest magnitude odds ratio. Some point estimates of risk were higher for the troponin = 1 and ECG = 1 point groups than the corresponding 2 points groups, which had small sample sizes.

3.3 | Sensitivity analyses

Patients with very-low-risk HEART scores of 0 to 3 were similar but no patients experienced acute myocardial infarction or death in the history = 2, ECG = 2, and troponin = 2 groups. Results with ECG = 1 or 2 and troponin = 1 or 2 points grouped together closely followed the 1-point groups, and all other coefficients were unchanged (footnotes to Table 2).

3.4 | Secondary results

Among the 135 total encounters with acute myocardial infarction or death within 30 days, the initial troponin used for calculation of the HEART score was generally well below the 0.50 ng/mL cutoff used as criteria for exclusion. Specifically, troponin was >3 times the normal limit (>0.12 ng/mL, but still <0.50 ng/mL) in only 1 encounter

TABLE 1 Patient characteristics of ED encounters

	Died or AMI (n = 135)	No outcome (n = 30,836)	Total (n = 30,971)
HEART Score			
0 to 3 points (very-low-risk)	41 (30.4%)	19,716 (63.9%)	19,757 (63.8%)
4 to 5 points (low- but not very-low-risk)	94 (69.6%)	11,120 (36.1%)	11,214 (36.2%)
Age, mean (SD)	66.0 (14.0)	58.7 (15.3)	58.7 (15.3)
Sex, female	58 (43.0%)	17,662 (57.3%)	17,720 (57.2%)
Education, college or higher, mean (SD)	55.2% (18.85)	57.0% (18.74)	56.9% (18.74)
Household median income, mean (SD)	65.5K (28.6K)	68.5K (28.4K)	68.5K (28.4K)
Race			
Alaska Native/Pacific Islander	2 (1.5%)	395 (1.3%)	397 (1.3%)
Asian	13 (9.6%)	2710 (8.8%)	2723 (8.8%)
Black	15 (11.1%)	4896 (15.9%)	4911 (15.9%)
Hispanic	51 (37.8%)	11,302 (36.7%)	11,353 (36.7%)
Others	0 (0%)	507 (1.6%)	507 (1.6%)
White	54 (40%)	11,026 (35.8%)	11,080 (35.8%)
BMI			
Underweight <18.5	5 (3.7%)	384 (1.2%)	389 (1.3%)
Normal 18.5–24.9	41 (30.4%)	6391 (20.7%)	6432 (20.8%)
Overweight 25–29.9	42 (31.1%)	10,036 (32.5%)	10,078 (32.5%)
Obese 30+	46 (34.1%)	13,594 (44.1%)	13,640 (44%)
Missing	1 (0.7%)	431 (1.4%)	432 (1.4%)
Smoking			
Never or passive	62 (45.9%)	18,650 (60.5%)	18,712 (60.4%)
Quit	55 (40.7%)	9232 (29.9%)	9287 (30%)
Active	18 (13.3%)	2135 (6.9%)	2153 (7%)
Missing	0 (0%)	819 (2.7%)	819 (2.6%)
Comorbidities (in year prior)			
Coronary artery disease	41 (30.4%)	4879 (15.8%)	4920 (15.9%)
Diabetes	66 (48.9%)	8932 (29%)	8998 (29.1%)
Hypertension	102 (75.6%)	17,183 (55.7%)	17,285 (55.8%)
Lipid disorder	102 (75.6%)	18,785 (60.9%)	18,887 (61%)
Stroke	14 (10.4%)	984 (3.2%)	998 (3.2%)
CABG	0 (0%)	110 (0.4%)	110 (0.4%)
Percutaneous coronary angioplasty	7 (5.2%)	197 (0.6%)	204 (0.7%)
Family history of coronary artery disease	51 (37.8%)	10,785 (35%)	10,836 (35%)
Family history of stroke	26 (19.3%)	5927 (19.2%)	5953 (19.2%)

Abbreviations: AMI, acute myocardial infarction; BMI, body mass index.

resulting in 30-day acute myocardial infarction or death (0.7%); it was 1- to 3-times the normal limit (0.05 to 0.12 ng/mL) in 22 encounters (16%); and it was within normal limits (up to 0.04 ng/mL) in 112 encounters (83%), among whom it was undetectable (<0.02 ng/mL) in 67 encounters (50%). In contrast, among the 965 patients who were excluded from the cohort due to an acute myocardial infarction diagnosed during their index ED visit, 437 (45%) had a troponin >0.50 ng/mL.

4 | LIMITATIONS

First, unlike other studies, patients with acute myocardial infarction diagnosed during their initial ED visit were not included, because we aimed to focus on low-risk patients who could be further evaluated as outpatients after their ED visit based on the HEART score.[6] Although subsequent troponin elevations may influence the diagnosis of acute myocardial infarction and could lead to endogeneity bias because

TABLE 2 Association of AMI or death with HEART components

HEART score component	Odds ratio (95% CI)* if p < 0.05	Low-risk scores (0-5)			Very low-risk scores (0–3)		
		Total (n)	AMI/death (n)	AMI/death % (95% CI)	Total (n)	AMI/death (n)	AMI/death % (95% CI)
History = 0 slightly suspicious	Ref	23,869	102	0.4 (0.4, 0.5)	17,564	40	0.2 (0.2, 0.3)
History = 1 moderately suspicious	1.0 (0.6, 1.6)	6210	28	0.5 (0.3, 0.7)	2071	1	0.0 (0.0, 0.3)
History = 2 highly suspicious	1.8 (0.6, 5.5)	892	5	0.6 (0.2, 1.3)	81	0	0.0 (0.0, 4.5)
ECG = 0 normal	Ref	22,446	72	0.3 (0.3, 0.4)	16,960	38	0.2 (0.2, 0.3)
ECG = 1 non-specific repolarization	2.2* (1.6, 3.2)	8390	62	0.7 (0.6, 1.0)	2728	3	0.1 (0.0, 0.3)
ECG = 2 significant ST deviation[a]	3.5(0.5, 23.7)	135	1	0.7 (0.0, 4.1)	28	0	0.0 (0.0, 12.3)
Age = 0 <45	Ref	5715	11	0.2 (0.1, 0.3)	5512	5	0.1 (0.0, 0.2)
Age = 1 45–64	1.2 (0.6, 2.5)	14,117	49	0.3 (0.3, 0.5)	10,584	22	0.2 (0.1, 0.3)
Age = 2 ≥65	2.1* (1.0, 4.3)	11,139	75	0.7 (0.5, 0.8)	3,620	14	0.4 (0.2, 0.7)
Risk = 0 (no known risk factors)	Ref	5795	6	0.1 (0.0, 0.2)	5690	5	0.1 (0.0, 0.2)
Risk = 1 (1–2 risk factors)	2.4* (1.0, 5.6)	16,287	62	0.4 (0.3, 0.5)	12,363	27	0.2 (0.1, 0.3)
Risk = 2 (3+ risk factors/atherosclerosis)	4.2* (1.8, 10.2)	8889	67	0.8 (0.6, 1.0)	1663	9	0.5 (0.3, 1.0)
Troponin = 0 (<normal limit)	Ref	30,055	112	0.4 (0.3, 0.5)	19,520	40	0.2 (0.2, 0.3)
Troponin = 1 1–3× normal limit	6.0* (3.3, 10.8)	805	22	2.7 (1.7, 4.1)	182	1	0.5 (0.0, 3.0)
Troponin = 2[b] >3× normal limit	3.6 (0.5, 24.9)	111	1	0.9 (0.0, 4.9)	14	0	0.0 (0.0, 23.2)

Abbreviation: AMI, acute myocardial infarction.

[a]Combining ECG = 1 or 2 points groups: odds ratio = 2.3* (1.6, 3.2); among 8525 low-risk scores, 63 AMI/deaths, 0.7% (0.6%, 0.9%); among 2,756 very-low-risk scores, 3 AMI/deaths, 0.1% (0.0%, 0.3%).

[b]Combining troponin = 1 or 2 points groups: odds ratio = 5.8* (3.3, 10.3); among 916 low-risk scores, 23 AMI/deaths, 2.5% (1.6%, 3.7%); among 196 very-low-risk scores, 1 AMI/death, 0.5% (0.0%, 2.8%).

troponin elevation was also a predictor, the troponin results used in calculation of the initial HEART score were drawn during the index ED visit and were generally much lower than those seen in patients when patients were later diagnosed with acute myocardial infarction.

Second, although the 0.04 ng/mL troponin upper limit of normal used here differs from the 0.02 ng/mL limit of detectability used at some other sites, we expect that using a lower cut-off—or a newer high-sensitivity troponin assay—would simply further reduce risk estimates for all groups, and this would benefit from future study.

Third, the subjectivity inherent in decisionmaking about revascularization led us to exclude this from our primary outcome, unlike some prior validations of the HEART score[7]; however, sensitivity analysis in our prior work on this patient population demonstrated similar rates of major adverse coronary events, which includes revascularization.

Fourth, the presence of a system-wide guideline encouraging discharge for HEART scores of 0 to 3 may influence clinician assessments of subjective components of the HEART score, although this could bias our cohort toward higher or lower risk, because clinicians may wish to improve flow through additional discharges or limit risk through additional admissions. Although deviations from this guideline were generally more common among higher-risk patients, we would expect this to bias our risk estimates toward the null.

Finally, although the study sites are part of an integrated health system that may offer more consistent outpatient follow-up and less use of revascularization than fee-for-service health systems, this system also allows us to capture all health system members diagnosed with acute myocardial infarction outside of our health system.

5 | DISCUSSION

In this large analysis of ED patients being evaluated for acute coronary syndrome, we found that the overall rate of acute myocardial infarction or death for patients with low-risk HEART scores of 0 to 5 was quite low at 0.4%. However, our results suggest that an even slightly elevated troponin component (troponin = 1 or 2 points), based on the first

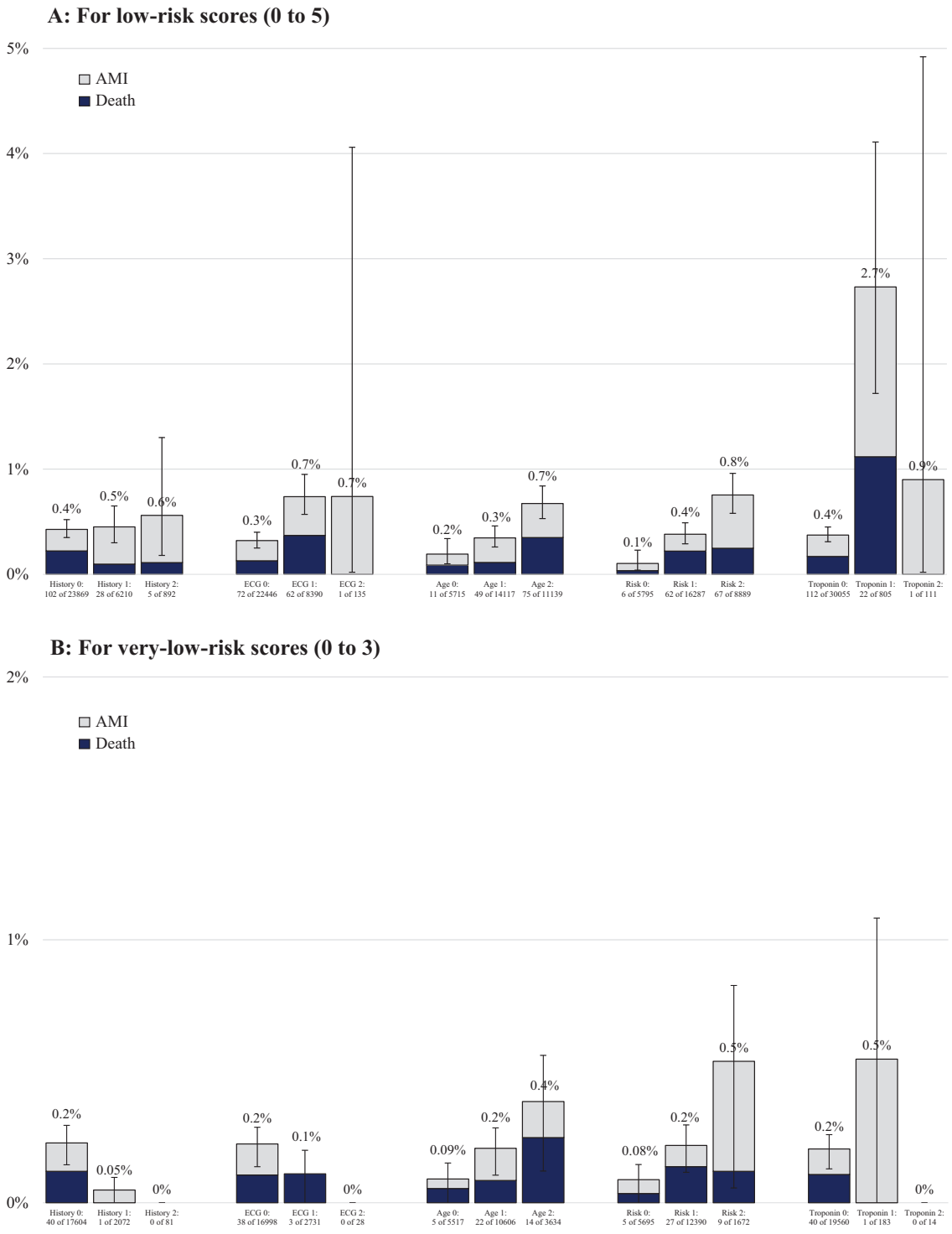

FIGURE 1 Acute chest pain reference HEART score algorithm

troponin value obtained on arrival, confers greater risk of acute myocardial infarction or death than the other components. The unadjusted risk of acute myocardial infarction or death seen in low-risk patients with a troponin = 1 point component are at least triple those of any other subgroup, despite having similar total scores in the remainder of the components of the HEART score. Odds ratios (that adjust for risk conferred by other score components) for any elevated troponin (troponin = 1 or 2 points) are larger than any other component. Although the odds ratios for troponin = 2 points were actually lower than for troponin = 1 point, the point estimate had very

wide confidence intervals driven by a single patient experiencing a non-fatal acute myocardial infarction.

Prior studies of the HEART score have recognized the elevated risk associated with elevated troponin values by excluding patients with any troponin abnormality on a conventional cardiac troponin assay (essentially reverting to an HEAR score that cannot risk stratify patients with slightly elevated troponins).[8] Meanwhile, some decision tools, such as the T-MACS score, use precise values from high-sensitivity troponin assays to generate continuous risk estimates from, but are too complex to compute without integrated electronic decision support tools.[9] This study attempts to combine these approaches by leveraging the existing HEART score to identify patients who may be at higher risk.

In summary, our large analysis of ED patients being evaluated for acute coronary syndrome shows that HEART scores of 0–5 are generally at low risk for death or acute myocardial infarction within 30 days, but points obtained from different components of the score are associated with different risk elevations. Specifically, any points obtained due to elevated troponin values (even in the intermediate range, corresponding to troponin = 1 or 2 points) as well as ST deviations (corresponding to ECG = 2 points) were predictive of higher risk than an equal number of points obtained from the other components. Although the HEART score still reliably identifies low-risk ED patients, further research on refinements to the score (eg, allocating additional points to the troponin component and correspondingly recalibrating the cut-off score to better match a 1% acceptable risk threshold for further testing) may better assess the risks facing patients with suspected acute coronary syndrome, allow for better risk stratification of patients with chest pain, and merits further study. Clinicians may also consider increased caution in patients with elevated troponin values.

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AUTHOR CONTRIBUTIONS

BCS and ALS secured funding for the study. YLW and ASB collected the data. ASB, YLW, and ES were responsible for the statistical analyses. KLHI led the project and drafted the manuscript. All co-authors (BCS, RSR, MSL, MF, YLW, ES, CZ, VM, and SJP) assisted with the study design, interpretation of the results, and editing of the manuscript. KLHI and ALS take final responsibility for the findings.

CONFLICTS OF INTEREST

BCS was a consultant for Medtronic. The other authors declare no conflicts of interest.

ORCID

Kimon L.H. Ioannides MD https://orcid.org/0000-0002-6384-2235

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AUTHOR BIOGRAPHY

Kimon L.H. Ioannides, MD, is an emergency physician and a fellow with the National Clinician Scholars Program at the University of California, Los Angeles

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