Prognostic Utility of a Modified HEART Score in Chest Pain Patients in the Emergency Department

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Background—The TRAPID-AMI trial study (High-Sensitivity Troponin-T Assay for Rapid Rule-Out of Acute Myocardial Infarction) evaluated high-sensitivity cardiac troponin-T (hs-cTnT) in a 1-hour acute myocardial infarction (AMI) exclusion algorithm. Our study objective was to evaluate the prognostic utility of a modified HEART score (m-HS) within this trial.

Methods and Results—Twelve centers evaluated 1282 patients in the emergency department for possible AMI from 2011 to 2013. Measurements of hs-cTnT (99th percentile, 14 ng/L) were performed at 0, 1, 2, and 4 to 14 hours. Evaluation for major adverse cardiac events (MACEs) occurred at 30 days (death or AMI). Low-risk patients had an m-HS≤3 and had either hs-cTnT<14 ng/L over serial testing or had AMI excluded by the 1-hour protocol. By the 1-hour protocol, 777 (60%) patients had an AMI excluded. Of those 777 patients, 515 (66.3%) patients had an m-HS≤3, with 1 (0.2%) patient having a MACE, and 262 (33.7%) patients had an m-HS≥4, with 6 (2.3%) patients having MACEs (*P*=0.007). Over 4 to 14 hours, 661 patients had a hs-cTnT<14 ng/L. Of those 661 patients, 413 (62.5%) patients had an m-HS≤3, with 1 (0.2%) patient having a MACE, and 248 (37.5%) patients had an m-HS≥4, with 5 (2.0%) patients having MACEs (*P*=0.03).

Conclusions—Serial testing of hs-cTnT over 1 hour along with application of an m-HS identified a low-risk population that might be able to be directly discharged from the emergency department. (*Circ Cardiovasc Qual Outcomes*. **2017;10:e003101. DOI: 10.1161/CIRCOUTCOMES.116.003101.**)

Key Words: mortality ■ myocardial infarction ■ patient discharge ■ prognosis ■ troponin-T

Approximately 5% to 10% of emergency department (ED) visits are for an evaluation for possible acute myocardial infarction (AMI).[1] In the United States, 8 to 10 million people are evaluated annually for possible AMI.[2] Ultimately, 85% of these patients are not diagnosed with AMI,[3–5] although they account for up to 25% of hospital admissions.[1] Furthermore, 2% of AMI cases are inadvertently discharged from the ED, leading to worse outcomes and medical–legal issues.[6] In the United States, $10 to $13 billion is spent annually evaluating patients with possible AMI in the ED.[7,8] The majority of these patients undergo a period of observation involving serial cardiac markers and stress testing or cardiac imaging (a strategy which is supported by the American College of Cardiology/American Heart Association).[9] This practice leads to increased costs but also to ED overcrowding, which has been associated with worse outcomes.[10,11]

The HEART score (HS) was designed to aid in the risk stratification of patients with undifferentiated chest pain in the

WHAT IS KNOWN

- Eight to 10 million individuals are evaluated annually in the emergency departments in the United States for possible acute myocardial infarction.
- Many of these individuals are evaluated with serial cardiac markers and held in observation units for stress testing or cardiac imaging, which is time-consuming and costly.

WHAT THE STUDY ADDS

- Excluding acute myocardial infraction with a 1-hour protocol using high-sensitivity cardiac troponin-T in patients with a low HEART Score (≤3) identifies a low-risk group that might be able to be immediately discharged from the emergency department without further cardiac testing.
- Using such a risk-stratification strategy is likely to be more impactful in the United States.
- Patients with a higher risk HEART score (≥4) will require cardiac troponin testing over a longer period of time.

ED.[12,13] The HS incorporates elements of the history, ECG, age, risk factors, and cardiac troponin (cTn) levels of patients to yield a lowest score of 0 (very low risk) up to a score of 10 (very high risk). Studies have demonstrated that an HS≤3 suggests a low-risk patient.[12–16] One study of 1070 patients demonstrated that those with a HS≤3 with normal serial cTnI values over 4 to 6 hours had an adverse event rate (death, AMI, or revascularization procedure) of 0% at 30 days.[14]

The new high-sensitivity cTnI and cTnT assays (hs-cTnI and hs-cTnT) offer advantages when compared with the prior assays. Many patients thought to have unstable angina because of normal cTn values as measured by older assays are now identified to have AMI as measured by the newer hs-cTn assays.[17] These patients will benefit from aggressive AMI treatments.[18]

The hs-cTn assays may also exclude AMI more rapidly. Mueller et al[19,20] studied a rule-out AMI protocol that evaluated changes in hs-cTnT over 1 hour. They showed 96.7% to 100% sensitivity and 99.1% to 100% negative predictive value. The aim of this study was to evaluate whether a modified HS (m-HS), a combination of the HS with serial hs-cTnT measurements, including the 1-hour AMI exclusion algorithm, could identify a low-risk patient population in those evaluated for possible AMI in the ED.

Methods

Study Design and Population

The TRAPID-AMI study (High-Sensitivity Cardiac Troponin-T Assay for RAPID Rule-Out of Acute Myocardial Infarction) was a prospective, multicenter, international diagnostic study to validate the performance of a 1-hour algorithm using the hs-cTnT assay for rapid rule-in and rule-out of AMI in the ED. Details regarding the study have been published.[20] The primary outcome of the study was the negative predictive value for AMI from the 1-hour algorithm:

hs-cTnT<12 ng/L at presentation and a change of <3 ng/mL at 1 hour. The value of 12 ng/L is less than the value at the 99th percentile of 14 ng/L, which is normally applied when a single cut point is used. A prespecified substudy of the TRAPID-AMI study evaluating a m-HS was conducted to identify a low-risk group of patients. The study was approved by local ethics committees.

The original study was conducted from August 2011 to June 2013 and included 12 centers in Europe, Australia, and the United States, which enrolled 1282 patients evaluated in the ED for possible AMI. Patients were included if they had chest discomfort suggestive of AMI, and the onset or peak of chest discomfort was 6 hours or less prior to presentation to the ED (median 2.7 hours, 25th percentile 1.5 hours, and 75th percentile 5.1 hours). To perform the study blood draw as quickly as possible a definite ECG interpretation was not required before inclusion. Therefore, ST-segment–elevation myocardial infarction patients were not excluded. Patients were excluded if they had chronic renal failure requiring hemodialysis. Participants provided written informed consent.

Investigational cTn Analysis

Blood samples for hs-cTnT (Roche Diagnostics, Penzberg, Germany) and cTnI-Ultra (Siemens Healthcare) were collected at 0, 1, 2, and 4 to 14 hours. After centrifugation, samples were frozen at −80°C until assayed in a blind fashion using the Elecsys 2010 (Roche Diagnostics) in a core laboratory. The limit of detection, 10% coefficient of variation, and 99th percentile of a reference population have been reported at 5, 13, and 14 ng/L, respectively.[21] The cTnI-Ultra assay was performed using the Siemens ADVIA Centaur with a limit of detection, 10% coefficient of variation, and 99th percentile of 6, 30, and 40 ng/L, respectively.[22,23]

Modified HS Criteria

Elements of the traditional HS have been described in prior studies.[12,13,15] The calculation of the HS includes elements of the history, ECG, age, and risk factors (Table 1). Each of these categories are assigned a 0 (low risk), 1 (moderate risk), or 2 (high risk) and then added into a composite score. The history was categorized retrospectively as either high, moderate, or low suspicion for AMI by using a modified Diamond–Forrester prediction rule,[24] including the presence of chest pressure, worsening with physical activity, and radiation to arms or shoulders. Relief of symptoms with rest, used in the original Diamond–Forrester tool, was not used because this information was not collected. Studies have shown that chest pressure and radiation to the arms to be predictive of AMI.[25,26] Patients were assigned 2 points if they met 3, 1 point if they met 2, and 0 points if they met 1 or none of the criteria.

Table 1.   Composition of Modified HEART Score

History (symptoms)	High suspicion	2
	Moderate suspicion	1
	Low suspicion	0
ECG	ST depression/elevation	2
	Left or right bundle branch block, left ventricular hypertrophy, or paced rhythm	1
	Nonspecific changes	0
Age	≥65 y	2
	45–64 y	1
	<45 y	0
Risk factors	≥3 risk factors or history of atherosclerotic disease	2
	1 or 2 risk factors	1
	No risk factors	0

Total=0–8.

For ECG findings, 2 points were given if there was horizontal or down-sloping ST depression ≥0.5 mm in 2 contiguous leads or ST elevation ≥1 mm in 2 contiguous leads (if V2-V3 was involved, then the following applied: ≥2 mm in males ≥40 years, ≥2.5 mm in males <40 years, and ≥1.5 mm in females); 1 point was given for either right or left bundle branch block, left ventricular hypertrophy, or ventricular paced rhythm; 0 point was given if the ECG did not meet any of the criteria of the other 2 categories. ECGs were categorized by independent cardiologists who were blinded to all clinical information.

Patients ≥65 years of age were assigned 2 points, those 45 to 64 years were given 1 point, and patients <45 years received 0 point. For risk factors, patients were assigned 2 points for ≥3 cardiac risk factors or a history of coronary artery disease (prior AMI, percutaneous coronary intervention, or coronary artery bypass grafting surgery), 1 point for 1 to 2 cardiac risk factors, and 0 point for 0 risk factors. Cardiac risk factors included in this analysis were hypertension, diabetes mellitus, and smoking history. Hyperlipidemia and family history were not included because this information was not collected. To be considered, low-risk patients had to have either a hs-cTnT<14 ng/L at various time points or rule-out for AMI by the 1-hour algorithm and have a HS≤3 for the remaining 4 categories (low-risk m-HS). The prognostic ability of the m-HS was compared with that of a modified Thrombolysis in Myocardial Infarction (TIMI) score.

Outcomes

The primary outcome was major adverse cardiac events (MACE) at 30 days: all-cause death or AMI. Revascularization procedures were not considered a MACE but were recorded. The diagnosis of AMI was defined as recommended by current guidelines.[27] AMI was diagnosed when there was evidence of myocardial necrosis on the basis of a significant rise or fall pattern of the cTn concentration in a clinical setting consistent with myocardial ischemia (ischemic symptoms, ECG changes, or imaging evidence). The cTnI-Ultra assay was used to diagnose AMI. The 99th percentile of this assay (40 ng/L) was used as a cutoff for myocardial necrosis. An absolute change of ≥20 ng/L with the cTnI-Ultra assay during the study period was used to define a significant change.[28] Each case of AMI was independently reviewed by 2 cardiologists and adjudicated by a third cardiologist in case of disagreement. After discharge, patients were contacted after 1 week and 30 days by telephone or in written form to obtain information regarding MACE. Information regarding death was furthermore obtained from the national registry on mortality, the hospital's diagnosis registry, and the primary care records.

Statistical Analysis

The Chi-squared test was used to evaluate the association of the established m-HS cut point (≤3 versus ≥4) and the established modified TIMI score cut points (0 versus ≥1 and 0 or 1 versus ≥2) with death or AMI at 30 days. The ability of the m-HS and modified TIMI scores to predict 30-day adverse event status was evaluated by obtaining the areas under the resulting receiver operator characteristic curves (AUC). Using the established m-HS and modified TIMI score cut points, the proportion of patients who had a nonelevated m-HS was compared with the proportion of patients who had a nonelevated modified TIMI score using the McNemar matched pairs test and the Chi-squared test for dichotomous characteristics. A descriptive comparison of the patients by AMI or death status at 30 days was performed using the Student 2-sample t test for age and the Fisher exact test for dichotomous characteristics. P values <0.05 have been considered statistically significant throughout the study. Analysis were conducted using SAS version 9.4 software.

Results

In the original TRAPID-AMI study, 1282 patients were evaluated, of which there were 213 (16.6%) AMIs (21 ST-segment–elevation myocardial infarctions) and 8 deaths. At 30 days, there were 2 additional AMIs diagnosed, yielding 217 (16.9%) patients with a 30-day MACE (6 patients had an AMI

and subsequently died). Because of missing data, 242 patients were excluded (Figure 1), leaving 1040 patients to be evaluated with the m-HS. Of these patients, 379 had an elevated hs-cTnT at 0 or 4 to 14 hours, yielding 661 patients for analysis at the 4- to 14-hour time point. Demographic information of the 661 patients comparing patients with an m-HS≤3 to those with an m-HS≥4 is shown in Table 2. The summary of the m-HS variables for the 661 patients are shown in Table 3. In these 661 patients, within 30 days, there were 6 (0.9%) MACEs (5 AMIs and 1 death). There were 413 (62.5%) patients categorized as low risk with an m-HS≤3. In the 413 patients with an m-HS≤3, there was 1 MACE (0.2%), which was an AMI; in the 248 patients with an m-HS≥4, there were
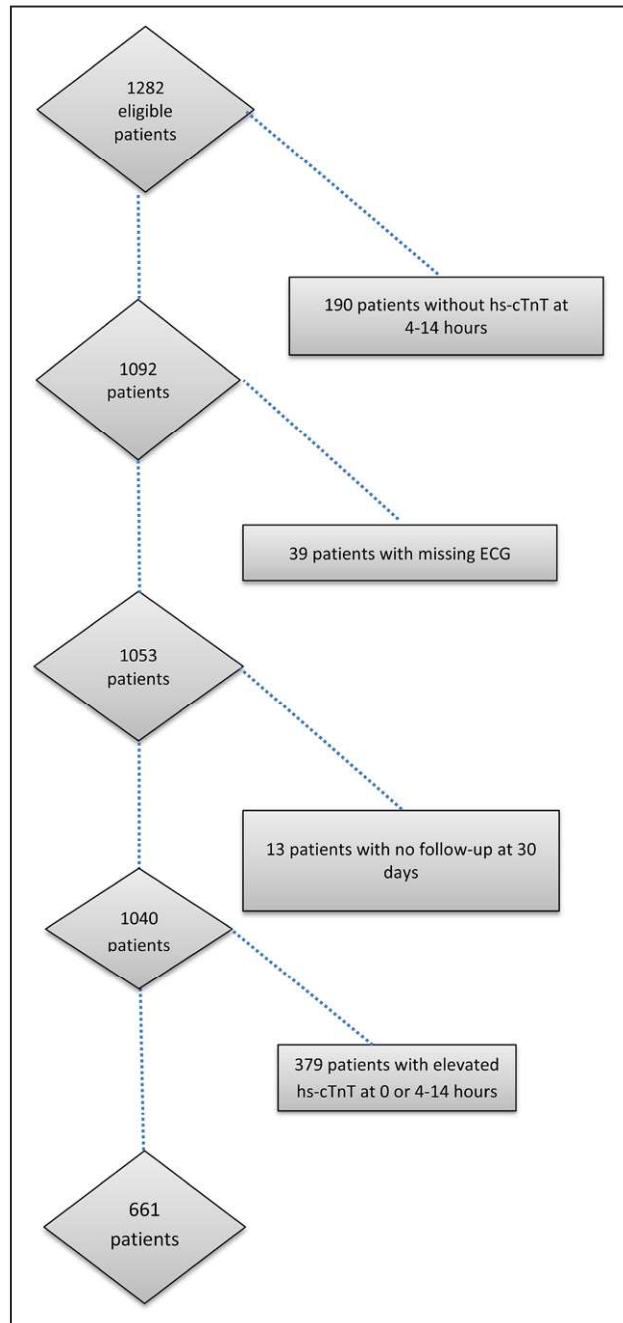
Figure 1. Patient flow diagram. hs-cTnT indicates high-sensitivity cardiac troponin-T.

Table 2. Demographic Characteristics

Variable	Overall Total (N=661)	Modified HEART Score ≤3 (n=413)	Modified HEART Score ≥4 (n=248)	Comparison P Value
Age±standard deviation	58.3±13.0	54.1±11.9	65.4±11.7	<0.001*
Male	385 (58.2%)	239 (57.9%)	146 (58.9%)	0.800
White	551 (83.4%)	333 (80.6%)	218 (87.9%)	0.015*
Hypertension	379 (57.3%)	186 (45.4%)	193 (79.1%)	<0.001*
Diabetes mellitus	110 (16.6%)	47 (11.5%)	63 (25.8%)	<0.001*
History of AMI	144 (21.8%)	37 (9.0%)	107 (43.7%)	<0.001*
History of percutaneous coronary intervention	179 (27.1%)	38 (9.3%)	141 (57.6%)	<0.001*
History of stable angina	72 (10.9%)	12 (2.9%)	60 (24.7%)	<0.001*
History of unstable angina	73 (11.0%)	22 (5.4%)	51 (21.1%)	<0.001*
History of congestive heart failure	19 (2.9%)	4 (1.0%)	15 (6.1%)	<0.001*
History of smoking	26 (3.9%)	12 (3.0%)	14 (5.8%)	0.077
Renal disease†	359 (54.3%)	217 (53.6%)	142 (58.7%)	0.207

AMI indicates acute myocardial infarction.

*Statistically significant, $P<0.05$.

†Renal disease: glomerular filtration rate <60 mL/1.73 m².

Table 3. Summary of the Modified HEART Score Variables

Variable	Category	hs-cTnT<14 ng/L at 0 and 4–14 h Total (N=661)	hs-cTnT<14 ng/L at 0 and 4–14 h m-HS≤3 (N=413)	hs-cTnT<14 ng/L at 0 and 4–14 h m-HS≥4 (N=248)
History (symptoms)	High suspicion	56 (8.5%)	7 (1.7%)	49 (19.8%)
	Moderate suspicion	221 (33.4%)	107 (25.9%)	114 (46.0%)
	Low suspicion	384 (58.1%)	299 (72.4%)	85 (34.3%)
ECG	ST depression or elevation	61 (9.2%)	5 (1.2%)	56 (22.6%)
	Left or right bundle branch block, left ventricular hypertrophy, or paced rhythm	49 (7.4%)	17 (4.1%)	32 (12.9%)
	Normal	551 (83.4%)	391 (94.7%)	160 (64.5%)
Age	≥65 y	206 (31.2%)	63 (15.3%)	143 (57.7%)
	45–64 y	358 (54.2%)	259 (62.7%)	99 (39.9%)
	<45 y	97 (14.7%)	91 (22.0%),	6 (2.4%)
Risk factors	≥3 risk factors or history of atherosclerotic disease	244 (36.9%)	60 (14.5%)	184 (74.2%)
	1 or 2 risk factors	318 (48.1%)	254 (61.5%)	64 (25.8%)
	No risk factors	99 (15.0%)	99 (24.0%)	0 (0.0%)

HS indicates HEART score; and hs-cTnT, high-sensitivity cardiac troponin-T.

5 (2.0%) MACEs (4 AMIs and 1 death; Figure 2; P=0.030). For the entire study group, the negative predictive value and sensitivity of the m-HS for an adverse event at 30 days was 99.8% (95% confidence interval, 98.7%–100.0%) and 93.8% (95% confidence interval, 89.6%–96.7%), respectively. In the patients with a hs-cTnT<14 ng/L at presentation and over 0 to 14 hours who had an m-HS≤3, 2.7% of patients had a revascularization procedure (11 percutaneous coronary interventions), while in those with an m-HS≥4, 9.3% of them had a revascularization procedure (22 percutaneous coronary interventions and 1 coronary artery bypass graft; P<0.001).

In the 661 patients with hs-cTnT<14 ng/mL over 4 to 14 hours, 299 (45.2%) underwent cardiac testing: stress testing without imaging, stress testing with imaging (myocardial perfusion imaging or echocardiography), coronary computed tomographic angiography (CCTA), or echocardiogram. In total, 192/413 (46.5%) patients with an m-HS≤3 underwent cardiac testing compared with 107/248 (43.1%) patients with an m-HS≥4, a difference that was not statistically significant (P=0.403). However, patients in the 2 United States sites were more frequently investigated with a cardiac test (93/125 [74.4%]), when compared with the 10 non-United States sites (206/536 [38.4%]; P<0.001).

Patients with an m-HS≤3 had lower MACE rates compared with those with an m-HS≥4 at each of the 4 time intervals of hs-cTnT measurement (Figure 2). Patients with an m-HS≤3 had a MACE rate <1% at all time points, and the MACE rate in patients with an m-HS≥4 ranged from 2.0% to

6.1% over the 4 time points. In addition, applying the m-HS to the 777 patients who were ruled-out by the 1-hour delta protocol, there were 6/262 (2.3%) patients who had a MACE with an m-HS≥4 and 1/515 (0.2%) patients who had a MACE (1 AMI) with an m-HS≤3 (P=0.007; Figure 3). In these 515 patients, there were 12 (2.3%) patients who had a revascularization procedure (all percutaneous interventions). Thus, 515/1282 (40%) patients of the entire study population could
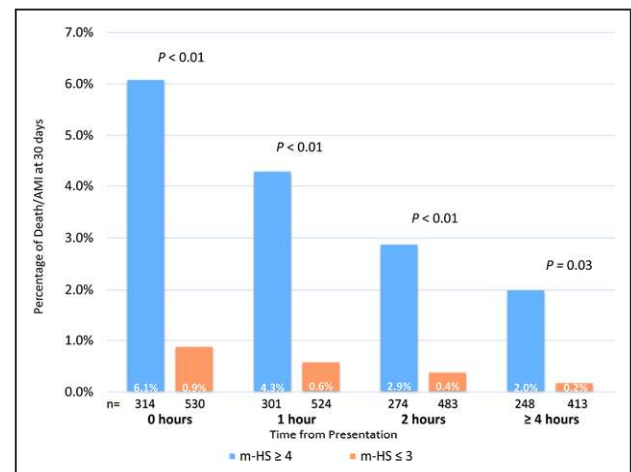
Figure 2. Death/acute myocardial infarction (AMI) at 30 days based on modified HEART score (m-HS) and high-sensitivity cardiac troponin-T (hs-cTnT) <14 ng/L over various time points.
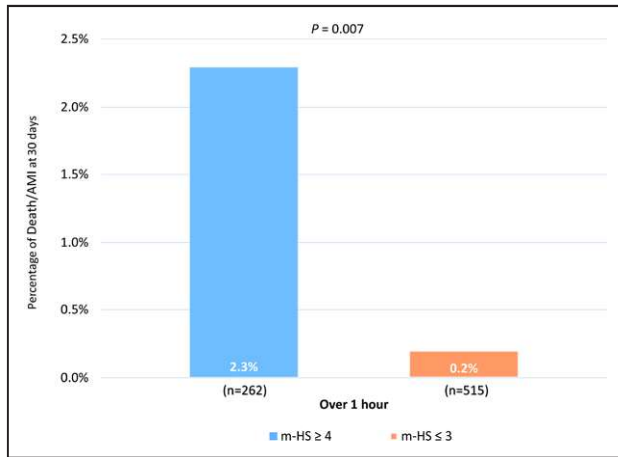
Figure 3. Death/acute myocardial infarction (AMI) at 30 days based on modified HEART score (m-HS) and high-sensitivity cardiac troponin-T (hs-cTnT) <12 ng/L at 0 hour and delta 1 hour <3 ng/L.

be identified as at very low risk by the 1-hour rule-out protocol and an m-HS≤3. In addition, hs-cTnT values were available in all patients at presentation and at 1 hour.

There are differences between the TIMI and HS. Although each category of the HS is assigned a number from 0 to 2, in the TIMI score, each category is only assigned a 0 or 1. Although each score includes age, ECG findings, risk factors, history of coronary artery disease, and troponin values, the TIMI score also includes aspirin use and recent episodes of angina. Both scores were modified in the sense of having negative hs-cTnT. The TIMI score was applied in 2 ways: a modified TIMI 0 score (TIMI score of 0 and negative hs-cTnT over 4–14 hours) and a modified TIMI 1 score (TIMI score of 0 or 1 and negative hs-cTnT over 4–14 hours). Of 650 analyzable patients, there were 200 (30.8%) with a modified TIMI 0 score and 366 (56.3%) with a modified TIMI 1 score. The m-HS≤3 identified significantly more patients as at low risk (62.5%) when compared with either the modified TIMI 0 score (30.8%) or the modified TIMI 1 score (56.3%; $P<0.05$ for both). For the 200 patients with a modified TIMI 0 score, there was 1 (0.5%) adverse event (1 AMI); for the 366 patients with a modified TIMI 1 score, there were 2 (0.5%) adverse events (1 death and 1 AMI). The prognostic utility (death or AMI at 30 days) by receiver operator characteristic curve analysis for the m-HS (AUC=0.748) was higher than the modified TIMI score (AUC=0.677), but the difference was not statistically significant ($P=0.15$).

Discussion

The main finding of our study is that a low-risk group can be identified in the ED in patients evaluated for possible AMI by applying an m-HS: serial hs-cTnT<14 ng/L over 4 to 14 hours or applying the 1-hour delta hs-cTnT algorithm and a HS≤3. In patients with a known hs-cTnT over 4 to 14 hours, there were 413/1053 (39.2%) such low-risk patients whose MACE rate (death or AMI) was 0.2% at 30 days. More notable is the finding that patients who rule-out for AMI by the 1-hour delta algorithm with an HS≤3 had a MACE rate of only 0.2%; there were 515/1282 (40.2%) such patients in our study. This

low-risk cohort of patients likely can be discharged directly from the ED after serial hs-cTnT testing using the 1-hour algorithm without further cardiac testing. Presently, many of these individuals are observed for a period of time until some form of stress testing or cardiac imaging are performed. Our study found that this practice of intense investigation happens more commonly in United States hospitals likely because of the medical–legal environment, suggesting that a strategy of early discharge would likely be even more impactful in the United States. This has not only significant resource and financial implications, but also other important ramifications.

When such low-risk patients are evaluated with cardiac testing, the likelihood for false positives is high. Hartsell et al[29] studied patients managed in an observation unit and found the false-positive rate for CCTA, stress testing with imaging (myocardial perfusion or echocardiography), and stress testing without imaging to be 43%, 67%, and 75%, respectively. Studies have also looked at CCTA in randomized studies of low-risk chest pain.[30–32] Goldstein et al[30] showed that patients randomized to CCTA spent less time in the ED and the hospital costs were less. However, Hoffman et al[32] showed that 30-day costs in low-risk chest pain were higher in patients randomized to CCTA, although this was not significant. Hoffman et al[32] also reported that patients randomized to CCTA received >2.5 times more radiation exposure. The use of computed tomographic scans has increased dramatically in recent years,[33] and it has been estimated that 2% of all cancers in the United States are related to the use of computed tomography scans.[34] Additionally, Litt et al[31] showed that patients randomized to CCTA received 3 times the rate of revascularization procedures. Whether these procedures actually improve patient outcomes remains uncertain in this patient population.

The HS was developed for the evaluation of patients with undifferentiated chest pain in the ED. These studies have reported a short-term MACE rate (AMI or death) between 0.6% and 1.4%.[13–15] These MACE rates are higher than what would be acceptable for an ED physician to discharge a patient without further evaluation. In a survey of ED physicians, the majority believed that a missed rate of AMI, and subsequent MACE, <0.5% is acceptable.[35] However, the original HS allowed the cTn levels to be considered in the score in a way that allowed a patient with an elevated cTn to be considered low risk. The original HS also only considered the initial cTn value, without taking serial sampling into account. This study and others suggest that when normal serial cTn values are combined with the HS, a very low–risk patient population can be identified, which could be discharged from the ED without further testing.[14] Mahler et al[36] demonstrated in a study of 282 patients that patients randomized to a HS strategy spent significantly less time in the hospital when compared with the standard of care, 9.9 hours versus 21.9 hours, respectively ($P<0.001$); no adverse events occurred at 30 days in either group.

The TIMI score has been applied to patients with chest pain of unclear etiology in the ED. Than et al[37] studied 1975 patients and identified a low-risk group with a TIMI score of 0 and nonelevated hs-cTnI values over 2 hours. They identified 392 (20%) patients as low risk with a 30-day MACE rate of 0.25%. In a similar trial of 1635 patients, Cullen et al[38]

identified a low-risk group with either a TIMI score of 0 or 1 and nonelevated hs-cTnI over 2 hours. They identified 351 (38.6%) patients as low risk, and the MACE rate was 0.3%. The TIMI score was generated in the patient population with definite AMI or unstable angina, excluding patients with an uncertain diagnosis.[39] When applied to patients in the ED with chest pain of unclear etiology, the TIMI score alone has not performed as well.[40] In a study of 3125 patients with chest pain of unclear etiology, the prognostic ability of the TIMI score to predict adverse events at 30 days was poor,[41] with an AUC of only 0.66. In a prospective multicenter study of 2440 patients, the HS outperformed the TIMI score.[13] For prognosis at 6 weeks, the AUC for the HS was 0.83, and for TIMI, it was 0.75 (P<0.0001). In our study, the m-HS with normal hs-cTnT values over 4 to 14 hours identified more low-risk patients (62.5%) when compared with either modified TIMI 0 (30.8%) or modified TIMI ≤1 (56.3%). However, there was only a trend for the m-HS to have better prognostic utility (AUC=0.748) when compared with a modified TIMI score (AUC=0.677). A larger study may have shown a significant difference.

Many clinical trials have defined MACE as the composite of death, AMI, or revascularization. In our study, we defined MACE as either death or AMI, and we think that this is more appropriate in low-risk patients evaluated in the ED for possible AMI. Revascularization is a softer end point as compared with death or AMI, and the need for revascularization can be subjective, which has been recognized by other authors.[42,43] The need for urgent revascularization has been used as an end point and thought to be a surrogate for unstable angina. However, with more sensitive cTn assays, the diagnosis of unstable angina has decreased significantly.[44,45]

This study has limitations. A modified Diamond–Forrester rule was retrospectively used as a surrogate for clinical suspicion because this information was not collected. Patients were included in the trial only if they had chest discomfort. Thus, patients with atypical symptoms without chest pain, which is especially common in older individuals who may present with only dyspnea or mental status changes, were not included similar to the initial validation of the HS.[13] This is relevant because these patients are known to have a worse prognosis as compared with AMI patients with chest pain.[46,47] Our findings should be validated in a broader population. The information on family history of coronary artery disease or hyperlipidemia was not available. With this information, there may have been fewer patients categorized as at low risk by the m-HS. Written informed consent was needed for participation, so patients who presented at night were underrepresented. A small number of patients had a MACE, although our MACE rate is similar to the findings of other studies.[13,48] Finally, there were 242 patients who had missing data. The majority of patients with missing data were 190 patients who did not have a hs-cTnT value at 4 to 14 hours. However, all patients had hs-cTnT measurements at presentation and at 1 hour where the 1-hour algorithm applies.

In conclusion, our study of an m-HS≤3 involving serial hs-cTnT measurements, which included a 1-hour delta rule-out AMI protocol, identified a low-risk cohort that could be considered for discharge from the ED without further cardiac testing. These findings should be validated prospectively.

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