

Clinical utility of the HEART score in patients admitted with chest pain to an inner-city hospital in the USA.

Soumya Patnaik

Mahek Shah MD

Lehigh Valley Health Network, Mahek.Shah@lvhn.org

Yaser Alhamshari

Pradhun Ram

Ritika Puri

See next page for additional authors

Follow this and additional works at: https://scholarlyworks.lvhn.org/cardiology_division



Part of the [Medicine and Health Sciences Commons](#)

Published In/Presented At

Patnaik, S., Shah, M., Alhamshari, Y., Ram, P., Puri, R., Lu, M., Balderia, P., Imms, J. B., Maludum, O., & Figueredo, V. M. (2017). Clinical utility of the HEART score in patients admitted with chest pain to an inner-city hospital in the USA. *Coronary artery disease*, 28(4), 336–341. <https://doi.org/10.1097/MCA.0000000000000474>

This Article is brought to you for free and open access by LVHN Scholarly Works. It has been accepted for inclusion in LVHN Scholarly Works by an authorized administrator. For more information, please contact LibraryServices@lvhn.org.

Authors

Soumya Patnaik, Mahek Shah MD, Yaser Alhamshari, Pradhun Ram, Ritika Puri, Marvin Lu, Percy Balderia, John B Imms, Obiora Maludum, and Vincent M Figueredo

Clinical utility of the HEART score in patients admitted with chest pain to an inner-city hospital in the USA

Soumya Patnaik^a, Mahek Shah^c, Yaser Alhamshari^a, Pradhun Ram^a, Ritika Puri^a, Marvin Lu^a, Percy Balderia^a, John B. Imms^a, Obiora Maludum^d and Vincent M. Figueredo^b

Background Chest pain is one of the most common presentations to a hospital, and appropriate triaging of these patients can be challenging. The HEART score has been used for such purposes in some countries and only a few validation studies from the USA are available. We aim to determine the utility of the HEART score in patients presenting with chest pain to an inner-city hospital in the USA.

Patients and methods We retrospectively screened 417 consecutive patients admitted with chest pain to the observation/telemetry units at Einstein Medical Center Philadelphia. After applying inclusion and exclusion criteria, 299 patients were included in the analysis. Patients were divided into low-risk (0–3) and intermediate-high (≥ 4)-risk HEART score groups. Baseline characteristics, thrombolysis in myocardial infarction score, need for revascularization during index hospitalization, and major adverse cardiovascular events (MACE) at 6 weeks and 12 months were recorded.

Results There were 98 and 201 patients in the low-score group and intermediate-high-score group, respectively. Compared with the low-score group, patients in the intermediate-high-risk group had a higher incidence of revascularization during the index hospital stay (16.4 vs. 0%; $P = 0.001$), longer hospital stay, higher MACE at 6 weeks

(9.5 vs. 0%) and 12 months (20.4 vs. 3.1%), and higher cardiac readmissions. HEART score of at least 4 independently predicted MACE at 12 months (odds ratio 7.456, 95% confidence interval: 2.175–25.56; $P = 0.001$) after adjusting for other risk factors in regression analysis.

Conclusion HEART score of at least 4 was predictive of worse outcomes in patients with chest pain in an inner-city USA hospital. If validated in multicenter prospective studies, the HEART score could potentially be useful in risk-stratifying patients presenting with chest pain in the USA and could impact clinical decision-making. *Coron Artery Dis* 28:336–341 Copyright © 2017 Wolters Kluwer Health, Inc. All rights reserved.

Coronary Artery Disease 2017, 28:336–341

Keywords: chest pain, HEART score, major adverse cardiovascular events risk stratification

^aDepartment of Medicine, ^bDepartment of Medicine, Division of Cardiology, Einstein Medical Center, Philadelphia, ^cDepartment of Cardiology, Lehigh Valley Healthcare Network, Allentown, Pennsylvania and ^dDepartment of Medicine, Wake Forest Baptist Medical Center, Winston-Salem, North Carolina, USA

Correspondence to Soumya Patnaik, MD, Einstein Medical Center, 5501 Old York Road, Klein 363, Philadelphia, PA 19141, USA
Tel: +1 2150 421 7388; e-mails: pat_soumya@yahoo.in, patnaiks@einstein.edu

Received 21 November 2016 Revised 23 January 2017
Accepted 30 January 2017

Background

Chest pain is one of the most common reasons for presentation to a hospital. Appropriate triaging is a challenging task, with uncertainties associated with the diagnoses of unstable angina and non-ST-elevation myocardial infarction (NSTEMI). In patients presenting to the emergency department with the complaint of chest pain, a misdiagnosis can result in poor outcomes, whereas an unnecessary hospitalization leads to higher patient dissatisfaction, overtreatment, and additional expenditure. Ruling out a possible acute coronary syndrome (ACS) in patients with non specific chest pain symptoms can be difficult, especially if an ECG is non-diagnostic, and cardiac enzymes are equivocal.

The HEART score was initially proposed by Six *et al.* [1] to facilitate quick triaging of chest pain patients in emergency rooms in the Netherlands [1–3]. The acronym

‘HEART’ stands for components of the scoring system: History, Electrocardiogram, Age, Risk factors, and Troponin. Risk stratification in this scoring system is detailed in Table 1. Each component can be scored with 0, 1, and 2 points depending on the extent of the abnormality. The HEART score is the sum total of these components.

Attempts have been made to validate the scoring system in the USA in recent years [4–6] as the population composition is fairly heterogeneous compared with Europe. Our study was carried out to determine the utility of the HEART score in patients presenting with chest pain to an inner-city hospital in the USA.

Patients and methods

This is a retrospective observational study that is based on an analysis of medical records and chart review of

Table 1 HEART score variables

| HEART score (sum total) | 0 | 1 | 2 |
|--|--|--|---|
| History | Slightly suspicious (noncardiac chest pain) ^a | Moderately suspicious (atypical angina) ^a | Highly suspicious (typical angina) ^a |
| Electrocardiogram | Normal | Nonspecific repolarization abnormalities | Significant ST depression |
| Age (years) | ≤ 45 | 45–65 | ≥ 65 |
| Risk factors (diabetes, hypertension, hyperlipidemia, obesity, family history) | None | 1–2 risk factors | ≥ 3 risk factors |
| Troponin | Normal | 1–3 × normal | > 3 × normal |

Adapted from Backus *et al.* [3]. Adaptations are themselves works protected by copyright. So in order to publish this adaptation, authorization must be obtained both from the owner of the copyright in the original work and from the owner of copyright in the translation or adaptation.

^aTypical angina has all three characteristics: (i) substernal chest discomfort with a characteristic quality and duration that is (ii) caused by exertion or emotional stress and (iii) relieved by rest or nitroglycerin. Atypical angina if two of the above characteristics are present. Noncardiac chest pain where only one or none of the above-mentioned characteristics are present.

patients admitted with chest pain to the observation and inpatient telemetry units at an academic inner-city hospital in Philadelphia. Permission to carry out the study was obtained from the institutional board review committee. 417 patients admitted consecutively for chest pain to observation and telemetry floors between 1 January 2013 and 31 August 2013 were screened and 299 patients were included after applying the inclusion and exclusion criteria. Adults more than 18 years, of both sexes, of any ethnic origin, irrespective of previous medical treatment, were included. Those with ST-elevation myocardial infarction (MI), decompensated congestive heart failure, or shock were excluded. Patients with inadequate data, and those who had not completed 1-year follow-up were excluded. Subsequent readmissions were excluded, and were considered in the outcome measurements. Routine demographic data (age, race, and sex), clinical history, and laboratory values were collected. Points for each component of the HEART score and the thrombolysis in myocardial infarction (TIMI) score at initial presentation were assigned. The predictive value of the HEART score for reaching an endpoint was evaluated. The end-points included need for revascularization during the index admission, major adverse cardiovascular events (MACE) at 6 weeks and 1 year, number of readmissions within the 1-year follow up, and 1-year all-cause mortality. MACE is a composite of events such as nonfatal MI, revascularization by sent placement or bypass, stroke, and death. Revascularization at the index admission was excluded from 6-week and 1-year MACE. Information on all-cause mortality was obtained using the Social Security Death Index. Total HEART scores were characterized as low (0–3) and intermediate-high (4–10) scores. All the outcomes were compared between the following two groups: low score group (0–3) and intermediate-high score (score ≥ 4) group.

Statistical analysis

Demographics and baseline characteristics were summarized using descriptive statistics. Continuous data were expressed as mean ± SD and analyzed using

Student's *t*-test. Fischer's exact test or χ^2 was used for analysis of categorical variables. Two separate logistic regression models were created. The first model evaluated the association between the intermediate-high HEART score group and MACE at 12 months after adjusting for age, race, sex, and BMI. In a second model, we used the widely validated high TIMI risk score (TIMI score ≥ 3) subgroup in place of the intermediate-high HEART score group and assessed its relationship in predicting MACE at 12 months after adjusting for the same variables. Results were considered statistically significant for *P* values less than 0.05. IBM SPSS statistics, version 20.0 (IBM Corp., Armonk, New York, USA) was used to carry out data analysis.

Results

Baseline characteristics

Of the 299 cases that were included in the study, 98 patients were in the low-score group and 201 were in the intermediate-high-score group. The mean age of the study population was 58.88 ± 14.35 years and approximately one-third of the patients were older than 65 years of age. Half (51%) of the patients were men and African-Americans constituted the majority (81.9%) of the study population. The mean BMI was 30.52 ± 7.31. The mean length of stay was 2.02 ± 1.87 days. In total, 84.8% of patients were hypertensive and 31.1% were smokers. The mean total HEART score was 4.37 ± 1.82. The mean TIMI score was 2.20 ± 1.45. Details of the baseline characteristics in each group are outlined in Table 2. The TIMI score is recorded in Table 3.

Outcomes

The low HEART score (*n* = 98) and intermediate-high-score (*n* = 201) groups had average scores of 2.45 ± 0.77 and 5.31 ± 1.40, respectively, and both groups were compared with respect to the outcomes. The length of hospital stay for initial event was longer in those with intermediate-high scores (2.25 ± 2.16 vs. 1.55 ± 0.91 days).

Of the 299 study patients, 33 (11%) reached the primary end-point (need for any revascularization at index admission), all of whom belonged to the intermediate-

Table 2 Baseline characteristics of the patients with low and intermediate-high HEART scores

| Characteristics | Low-score group (N=98) | Intermediate-high-score group (N=201) | P value |
|--------------------------------------|------------------------|---------------------------------------|---------|
| Age (mean ± SD) (years) | 52.99 ± 14.20 | 61.75 ± 13.56 | <0.001 |
| Male (%) | 49 | 51.7 | 0.201 |
| BMI (mean ± SD) (kg/m ²) | 29.22 ± 7.12 | 31.15 ± 7.33 | 0.032 |
| Race | | | 0.25 |
| Whites (%) | 4.1 | 9.5 | |
| African-Americans (%) | 83.7 | 81.1 | |
| Asians (%) | 1 | 2 | |
| Hispanics (%) | 10.2 | 5.5 | |
| Others (%) | 1 | 2 | |
| Length of stay (days) | 1.55 ± 0.92 | 2.25 ± 2.16 | 0.002 |
| Hypertension (%) | 69.4 | 91.5 | <0.01 |
| Diabetes (%) | 20.4 | 49.3 | <0.01 |
| Hyperlipidemia (%) | 34.7 | 63.2 | <0.01 |
| Obesity (%) | 22.4 | 47.3 | <0.01 |
| Family history of CAD (%) | 20.4 | 36.8 | 0.04 |
| Smoking (%) | 27.6 | 32.8 | 0.354 |
| Chronic kidney disease (%) | 9.2 | 21.9 | 0.007 |
| Previous history of ACS (%) | 11.2 | 41.8 | <0.01 |
| Previous angina (%) | 14.3 | 40.3 | <0.01 |
| Previous PCI/CABG (%) | 9.2 | 35.3 | <0.01 |
| Total HEART score (mean ± SD) | 2.45 ± 0.775 | 5.31 ± 1.40 | <0.001 |
| TIMI score (mean ± SD) | 1.07 ± 0.94 | 2.76 ± 1.33 | <0.01 |

ACS, acute coronary syndrome; CABG, coronary artery bypass graft; CAD, coronary artery disease; PCI, percutaneous coronary intervention; TIMI, thrombolysis in myocardial infarction.

high-score group. The revascularization rate at index admission within the low-score group ($n=98$) versus the intermediate-high-score group ($n=201$) is 0% versus 16.41% ($P<0.001$). Overall ($n=299$), 6-week and 1-year MACE rates were 6.4 and 12.7%, respectively. At the 6-week follow-up, the low-score group ($n=99$) did not experience any MACE, whereas 9.5% in the intermediate-high-score group ($n=201$) had a MACE ($P=0.002$). Similarly at 1 year, MACE rates were significantly higher in the intermediate-high-score group compared with the low-score group (20.4 vs. 3.1%, $P<0.01$) (Table 4 and Fig. 1). The number of cardiac readmissions at 1 year for the low-score and intermediate-high-score group were 0.43 ± 0.99 and 0.77 ± 1.24 , respectively.

Table 3 Components of the thrombolysis in myocardial infarction score

| | Low-score group (N=98) | Intermediate-high-score group (N=201) |
|--|------------------------|---------------------------------------|
| Age ≥ 65 years (%) | 19.38 | 38.3 |
| ≥ 3 risk factors (%) | 25.51 | 74.12 |
| Known CAD > 50% stenosis (%) | 7.14 | 31.34 |
| Use of aspirin in last 7 days (%) | 27.55 | 54.22 |
| Severe angina (>2 episodes in last 24 h) (%) | 21.42 | 41.29 |
| ST segment deviation > 0.5 mm (%) | 0 | 3.98 |
| Elevated cardiac markers (%) | 5.1 | 32.83 |
| Total TIMI score (mean ± SD) | 1.07 ± 0.94 | 2.76 ± 1.336 |

CAD, coronary artery disease; TIMI, thrombolysis in myocardial infarction.

Risk prediction model

The regression models showed that both HEART score of at least 4 [adjusted odds ratio 7.456, 95% confidence interval (CI): 2.175–25.56; $P=0.001$] and TIMI score of at least 3 (adjusted odds ratio 7.235, 95% CI: 3.193–16.395; $P<0.001$) independently predicted MACE at 12 months after adjusting for age, African-American race, sex, and BMI.

Discussion

When a patient presents to the emergency room with chest pain, the decision to discharge without a diagnosis causes insecurity; overdiagnosis and unnecessary admissions with many investigations lead to resource misutilization, patient dissatisfaction, and mistrust in the system. Attempts to triage such patients has produced several proposed scoring systems. A few of these scores have limited applicability for use in emergency rooms, and none is unanimously accepted in clinical practice. The PURSUIT and GRACE scores have not directly taken history into consideration [7–10]. The widely used TIMI score is similar, and useful for prognostication and therapeutic decision-making, although it does not take into account the patient's history. The TIMI score may be better suited for use in such patients with confirmed unstable angina/NSTEMI. Troponins were not included in the PURSUIT score, and this scoring is not used frequently in current practice.

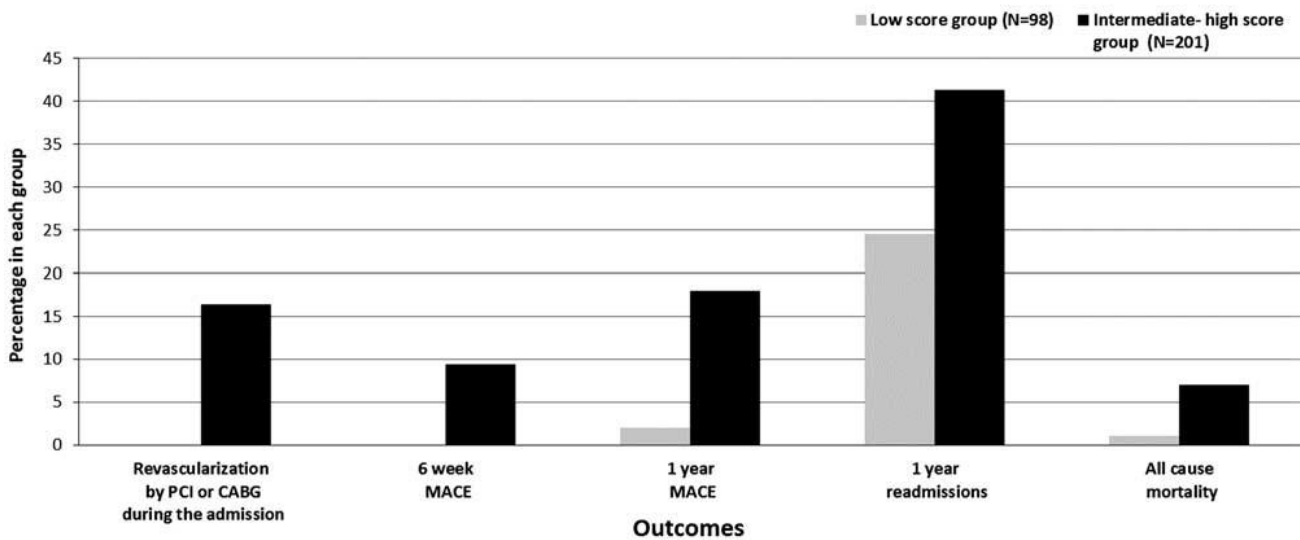
The HEART score is a tool that was introduced and validated in the Netherlands in 2008 to evaluate patients presenting with chest pain to the emergency room [1]. In a pilot study carried out on 122 patients, Six *et al.* [1] found that with a score less than 3, the chance of reaching an end-point was 2.5%. Endpoints included acute MI, revascularization by percutaneous coronary intervention/coronary artery bypass graft, death, and a combined endpoint of acute MI, coronary artery bypass graft, percutaneous coronary intervention, and death. When the score was more than 7, the chance of reaching any end-point increased to 72.7%. Most endpoints were observed within a 3-month time-frame.

The original authors then validated the score in a retrospective multicenter study in Europe involving analysis of 880 patients with chest pain [2]. Of these, 17.95%

Table 4 End points in low-score and intermediate-high-score groups for the HEART score

| End points | Low-score group (N=98) | Intermediate-high score group (N=201) | P value |
|---|------------------------|---------------------------------------|---------|
| Revascularization by PCI or CABG during the index admission (%) | 0 | 16.41 | <0.001 |
| Acute myocardial infarction in 6 weeks (%) | 0 | 3 | 0.084 |
| Revascularization by PCI/CABG in 6 weeks (%) | 0 | 7.5 | 0.006 |
| Cerebrovascular accident in 6 weeks (%) | 0 | 1 | 0.322 |
| All-cause mortality in 6 weeks (%) | 0 | 1 | 0.322 |
| 6-Week composite MACE (%) | 0 | 9.5 | 0.002 |
| Acute myocardial infarction in 1 year (%) | 0 | 4 | 0.045 |
| Revascularization by PCI/CABG in 1 year (%) | 0 | 12.9 | <0.01 |
| Cerebrovascular accident in 1 year (%) | 1 | 2.5 | 0.396 |
| All-cause mortality in 1 year (%) | 2 | 7 | 0.076 |
| 1-Year MACE (%) | 3.1 | 20.4 | <0.01 |
| Number of hospitalizations to telemetry/CCU in 1 year (mean±SD) | 0.43±0.99 | 0.77±1.2 | 0.019 |

CABG, coronary artery bypass graft; CCU, cardiac critical care unit; MACE, major adverse cardiovascular events (a composite of myocardial infarction, PCI, CABG, cerebrovascular accident, and death); PCI, percutaneous coronary intervention.

Fig. 1

End points for the low-score (0–3) and intermediate-high-score (≥ 4) groups. MACE, major adverse cardiovascular events.

($n=158$) reached the primary end point of MACE at 6 weeks. Of 303 patients with scores 0–3, only 3 (0.99%) had an end-point; 65.2% of those with scores 7–10 (107/164) reached an end-point. The HEART score was then convincingly proven to predict outcome in chest pain patients in European emergency rooms in multi-center prospective validation studies both within the Netherlands [3] and in a separate multinational study involving Europe and Asia-Pacific [11]. On the basis of these studies, the authors proposed that if the HEART score is 0–3, there is a low risk for 30-day MACE with more than 98% certainty, and reserved policies with an early discharge plan may be appropriate for this group. However, when the HEART score of at least 7, the risk of revascularization or MACE is significantly high, supporting the use of aggressive policies including an early revascularization strategy. In a study by Melki *et al.* [12]

in Sweden, 0.4% of the patients in the low-score group (0–3) reached the combined endpoint at 3 months (cardiovascular death, MI, unplanned revascularization). These authors proposed that the HEART score may be utilized to identify the low-risk group in which admission and further investigations may not be necessary.

The HEART score has, however, been validated only in a few studies in the USA [4–6]. The patient population in the USA is different from that in Europe. As per the US census bureau, population estimates from 2015 comprised of 77.1% Whites, 17.6% Hispanics, 13.3% African Americans, the rest were Asians and other ethnicities. The response to various medical interventions can be different in this population compared with Europeans, making it worthwhile to study the validity of the score in the USA population. Mahler *et al.* [4] studied 1070 low-risk patients from an emergency department-based

registry from 2008 to 2010. The MACE occurred in 0.6% when the HEART score was less than 3 compared with a rate of 4.2% in the high-risk HEART score group, with an odds ratio of 7.92 (95% CI: 2.48–25.25). HEART score more than 3 showed a sensitivity of 58% and a specificity of 85% for MACE in these patients. The authors concluded that the HEART score can markedly reduce the need for a stress test and cardiac imaging in low-risk patients [4]. When they used serum troponins more than 0.065 ng/ml as the cut-off in addition to HEART score more than 3, the sensitivity increased to 100% and the specificity was 83%, with a potential reduction in cardiac testing by 82%. Sun *et al.* [5] analyzed data from the Internet Tracking Registry of Acute Coronary Syndromes database from nine emergency rooms. They included 8255 patients during 1999–2001 in their analysis, and found that the HEART score was superior to the TIMI score in differentiating low-risk categories (HEART score < 3 and TIMI < 0) [5]. The study excluded patients who fulfilled the diagnostic criteria for ACS. In this study, HEART score 0–3 had a negative predictive value of 0.982, with 95% CI: 0.978–0.986 and a positive predictive value of 0.103 with 95% CI: 0.094–0.113, and was found to be superior to the TIMI score in the low-risk categories (TIMI 0–1). Jain *et al.* [6], in a study, included 947 patients from 1999 at Henry Ford Hospital in Detroit, MI, and found that the HEART score was a useful tool in predicting not only short-term MACE but also long-term mortality in patients evaluated for possible ACS in the emergency department. The authors concluded that the HEART score had a superior prognostic value compared with the TIMI score.

Our study is slightly different from these studies because it was carried out in a tertiary referral center serving an inner-city population in Philadelphia. We included patients admitted to the observation and telemetry units in 2013 retrospectively. African-Americans constituted the majority of our patients. In our study, we observed that patients in the low-risk group (score < 3) did not need revascularization during stay and had no MACE events within 6 weeks of admission. Thus, it may be reasonable to safely discharge patients within this group and follow them up as outpatients. It is possible that admissions in the low-risk group on the basis of currently standard admission criteria to rule out ACS are inappropriate and result in overutilization of resources. The worse outcomes in patients with intermediate-high HEART scores are not surprising because they are more often older than 65 years, more often had a previous history of angina or revascularizations, and presented with multiple risk factors such as obesity, hypertension, diabetes, hyperlipidemia, smoking, or a family history of premature cardiovascular disease. Patients with intermediate-high scores are at a significantly higher risk

and must be considered for inpatient admission and workup.

It is noteworthy that the simple user-friendly design of the HEART score and nondependence on a computer or a calculator can be utilized to triage these patients presenting with chest pain. It can be used as a guide for young clinicians to remember to take into account age and a comprehensive history, in addition to the electrocardiogram, baseline risk factor profile, and serial troponin levels. Compared with the TIMI score, the HEART score takes into account the characteristics of pain as a variable. The HEART score may therefore be more appropriate for use in patients with chest pain initially presenting in the emergency room or in the outpatient setting to identify patients with ACS. It can be a particularly useful tool for physicians in training, emergency room physicians, general internists, and those who do not have formal training in cardiology for low-risk patients presenting for chest pain. This scoring system may, however, be less appropriate for confirmed cases of ACS where factors such as response or trigger during exercise are usually not taken into account as patients with ACS present with rest pain. The TIMI score may be better suited for use in such patients with confirmed unstable angina/NSTEMI. It facilitates a uniform communication basis for physicians and can help in formulating early discharge policies for low-risk populations. This strategy may result in better resource utilization if this scoring system is validated in larger multicenter studies in the USA.

Limitations

This is a retrospective study where the score itself was not used to make clinical decisions. This is a single-center study and the sample size may not be adequate to draw firm conclusions. Our analysis did include a majority of African-American patients, an under-represented population in most studies, and may not be generalizable to the entire USA population. Many of the exclusions were because of inadequate data availability and a majority of these patients were admitted to observation units. Of all patients presenting to the emergency room with chest pain, we have only included patients admitted to the observation and telemetry units. Some patients who were discharged directly from the emergency room were not included. Also, some high-risk patients admitted to the medical-surgical or cardiac intensive care were missed. Extremely high-risk patients admitted to the cardiac ICU for confirmed ACS were excluded. The sample size is limited for validation of a continuous variable (the score), and we had to merge the intermediate-risk and high-risk groups. These limitations can be overcome by carrying out prospective multicentre prospective studies on a larger scale.

Conclusion

The HEART score is a simple tool to triage patients presenting to the emergency department with chest pain. A HEART score of at least 4 was predictive of worse outcomes at 6 weeks and 1 year among patients admitted with chest pain to an inner-city USA hospital. If validated in multicenter prospective studies, the HEART score has the potential to be useful in risk-stratifying patients presenting with chest pain in the USA and could impact clinical decision-making.

Acknowledgements

Dr Patnaik is the PI of the project under the mentorship of Dr Figueredo. Dr Patnaik designed the study, obtained IRB approval, performed data collection, and prepared the manuscript. Dr Shah helped in statistical analysis and preparation of the manuscript. Dr Alhamshari, Dr Ram, Dr Puri, Dr Lu, Dr Balderia, Dr Imms, and Dr Maludum helped in retrospective chart review and data collection. All authors have reviewed and approved the manuscript for submission.

Conflicts of interest

There are no conflicts of interest.

References

- 1 Six AJ, Backus BE, Kelder JC. Chest pain in the emergency room: value of the HEART score. *Neth Heart J* 2008; **16**:191–196.
- 2 Backus BE, Six AJ, Kelder JC, Mast TP, van den Akker F, Mast EG, *et al.* Chest pain in the emergency room. A multicenter validation of the HEART score. *Crit Pathw Cardiol* 2010; **9**:164–169.
- 3 Backus BE, Six AJ, Kelder JC, Bosschaert MAR, Mast EG, Mosterd A, *et al.* A prospective validation of the HEART score for chest pain patients at the emergency department. *Int J Cardiol* 2013; **168**:2153–2158.
- 4 Mahler SA, Hiestand BC, Goff DC, Hoekstra JW, Miller CD. Can the HEART score safely reduce stress testing and cardiac imaging in patients at low risk for acute coronary syndrome? *Crit Pathw Cardiol* 2011; **10**: 128–133.
- 5 Sun BC, Laure A, Fu R, Ferenak M, Shapiro M, *et al.* Comparison of the HEART and TIMI risk scores for suspected acute coronary syndrome in emergency department. *Crit Pathw Cardiol* 2016; **15**:1–5.
- 6 Jain T, Nowak R, Hudson M, Frisoli T, Jacobsen G, McCord J. Short- and long-term prognostic utility of the HEART score in patients evaluated in the emergency department for possible acute coronary syndrome. *Crit Pathw Cardiol* 2016; **15**:4–45.
- 7 Boersma E, Pieper KS, Steyerberg EW, Wilcox RG, Chang WC, Lee KL, *et al.* Predictors of outcome in patients with acute coronary syndromes without persistent ST-segment elevation. Results from an international trial of 9461 patients. The PURSUIT Investigators. *Circulation* 2000; **101**: 2557–2567.
- 8 Granger CB, Goldberg RJ, Dabbous OH, Pieper KS, Eagle KA, Cannon CP, *et al.* Global Registry of Acute Coronary Events Investigators. Predictors of hospital mortality in the global registry of acute coronary events. *Arch Intern Med* 2003; **163**:2345–2353.
- 9 Fox KA, Dabbous OH, Goldberg RJ, Pieper KS, Eagle KA, Avezum A, *et al.* Prediction of risk of death and myocardial infarction in the six months after presentation with acute coronary syndrome: prospective multinational observational study (GRACE). *BMJ* 2006; **333**:1091.
- 10 Antman EM, Cohen Mk, Bernink PJ, McCabe CH, Horacek T, Papuchis G, *et al.* The TIMI risk score for unstable angina/non-ST elevation MI. *JAMA* 2000; **284**:835–842.
- 11 Six AJ, Cullen L, Backus BE, Greenslade J, Parsonage W, Aldous S, *et al.* The HEART score for the assessment of patients with chest pain in the emergency department: a multinational validation study. *Crit Pathw Cardiol* 2013; **12**:121–126.
- 12 Melki D, Jernberg T. HEART score: a simple and useful tool that may lower the proportion of chest pain patients who are admitted. *Crit Pathw Cardiol* 2013; **12**:127–131.