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Original Contributions

HEART SCORE AND STRESS TEST EMERGENCY DEPARTMENT BAYESIAN DECISION SCHEME: RESULTS FROM THE ACUTE CARE DIAGNOSTIC COLLABORATION

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□ **Abstract—Background: Accurate identification of patients at risk of major adverse cardiac events (MACE) places a substantial burden on emergency physicians (EPs). Bayesian nomogram for risk stratification in low- to intermediate-risk cardiovascular patients has not been investigated previously. Objective: The objective of this study was to develop a comparative diagnostic model using Bayesian statistics for exercise treadmill test (ETT) and stress echocardiogram (ECHO) to calculate post-test diagnostic risk of MACE using HEART (history, electrocardiogram, age, risk factors, and troponin) risk score as predictor of pretest probability. Methods: Stratification was made by applying HEART scores for the prediction of MACE. Likelihood ratios (LR) were calculated using pooled sensitivity and specificity of ETT and ECHO from the American College of Cardiology Foundation/American Heart Association systematic review. Post-test probabilities were obtained after inserting HEART score and LR into Bayesian nomogram. Analysis of variance was used to assess statistical association. Results: Positive LR (LR+) for ETT was 4.56 and negative LR (LR–) was 0.27; for ECHO, LR+ 5.65 and LR– 0.15. Bayesian statistical modeling post-test probabilities for LR+ and low HEART risk yielded a post-test probability for ETT of 7.75% and 9.09% for ECHO; intermediate risk gave 47.62% and 52.63%, respectively. For LR–, low HEART risk post-test probability for ETT was 0.46% and for ECHO 0.26%; intermediate risk probabilities were 4.48% and 2.49%, respectively. LR– was statistically significant in ruling out MACE with ECHO ($p < 0.001$), but no significant differences were seen for LR+ ($p = 0.64$). Conclusions: This Bayesian analysis demonstrated slight superiority of stress ECHO over ETT in low- and intermediate-risk patients in ruling out MACE.**

□ **Keywords—HEART score; exercise stress test; ECHO; MACE**

INTRODUCTION

Major adverse cardiac events (MACE) account for 5%–10% of all emergency department (ED) visits for chest pain. It is defined as death due to cardiac complications, nonfatal myocardial infarction, and requirement of revascularization (1). Over the last few decades, many screening techniques and biomarkers have become resourceful tools to emergently identify MACE. For suspected acute coronary syndrome (ACS), emergency physicians rely on serial troponins and dynamic electrocardiogram changes to guide their clinical assessment (2–4). However, these values are not always diagnostic, and in order to assess risk in typical and atypical ACS

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patients, the standardized practice has evolved to use numerical risk scores (3).

A multitude of risk scores have been used throughout the last decade, such as PURSUIT (Platelet Glycoprotein IIb/IIIa in Unstable Angina: Receptor Suppression Using Integrilin Therapy), TIMI (Thrombolysis in Myocardial Infarction), FRISC (Fast Revascularization in Instability in Coronary Disease), and GRACE (Global Registry of Acute Coronary Events) (5,6). However, the most recent and mainstay pretest indicator of MACE has been the HEART score. Unlike the previously mentioned tests, the HEART score predicts MACE probability through risks based on age, cholesterol, blood pressure, and smoking status, as well as history and troponin levels (7). Based on the score, it stratifies and assigns a percentage of risk regarding the occurrence of MACE within the next 6 weeks: score 0–3 = 1.7% risk (low); 4–6 = 16.6% risk (intermediate); and 7–10 = 50.1% risk (high). It is important to note that in the original study published in 2008, the authors calculated higher risk percentages for the HEART scores, but a validation study in 2013 with 2440 patients re-analyzed the risk stratifications, as listed here (8,9). The HEART score has allowed clinicians to make clinical decisions in the ED.

For low- to moderate-risk patients, follow-up can involve a cardiac stress test to determine the presence of significant coronary artery disease. The two most common options include an exercise treadmill test (ETT) or a stress echocardiogram (ECHO) and thus were analyzed in this study. Each of these tests is associated with a specificity and sensitivity and, regardless of the technique, it is not clear to what extent the risk of MACE is increased or decreased with either of these risk assessment tools.

This study sought to develop a comparative diagnostic model using Bayesian statistics for ETT and stress ECHO to calculate post-test diagnostic risk of MACE using HEART risk score as a predictor of pretest probability.

METHODS

The Acute Care Diagnostic Collaboration is a multicenter, multinational research effort that introduces a Bayesian methodology and statistical modeling on pretest probability with emergency medicine clinical decision rules, combining it with assessments on diagnostic quality and cost effectiveness of clinical analytic tools in various patient populations.

Bayesian statistics rely on varying degrees of belief in an outcome to an event. Bayes' theorem links the degree of belief in a proposition before (pretest probability) and after (post-test probability) accounting for evidence, which is known as the Bayesian inference. The Bayesian nomogram is a graphical calculator that performs calculations without the need to remember the formula, which integrates pretest probability with diagnostic test LRs. The result is that the Bayesian nomogram simplifies diagnostic test information to be used more frequently by physicians. By employing Bayes' theorem, the initial clinical assessment is graded by means of probability and, when subsequently merged with clinical suspicion and diagnostic test results, either rules out or rules in the diagnosis (10–16).

The American College of Cardiology Foundation/American Heart Association 2012 Taskforce Guidelines, which referenced > 1000 studies in coronary artery disease patients, was selected in order to obtain the sensitivities and specificities of ETT and ECHO (17). The 2014 Guidelines were not used because they do not report any newly updated test characteristics for diagnostic tools.

Likelihood ratios (LRs) were used as epidemiologic instruments to show how much we should shift our suspicion for a particular test result. We defined the LR+ and LR– in terms of sensitivity and specificity:

$$\mathrm{LR}+ = \frac{\text{sensitivity}}{1 - \text{specificity}}$$

$$\mathrm{LR}- = \frac{1 - \text{sensitivity}}{\text{specificity}}$$

We computed positive and negative LRs (Table 1). We used Bayes' theorem to convert the results from the HEART score combined with a diagnostic test, ETT or ECHO, into the probability of the event. Bayes' math describes the analysis as a relation of $Pr(A|X)$, the chance that an event A happened, given the indicator X, and $Pr(X|A)$, the chance the indicator X happened, given that event A occurred. Our mathematical method uses Bayes' nomogram to determine post-test probability.

For the nomogram analysis, the pretest probability (Pre) scoring for HEART was obtained using the original HEART authors' derived data. Post-test probability (Post) was obtained from Bayesian statistical

Table 1. Sensitivity, Specificity, and Likelihood Ratios for Diagnostic Test

Diagnostic Test	Sensitivity, %	Specificity, %	LR+	LR–
Treadmill stress	77.5	83.0	4.56	0.27
Stress ECHO	87.5	84.5	5.65	0.15

ECHO = echocardiogram; LR = likelihood ratio.