Comparison of shock index-based risk indices for predicting in-hospital outcomes in patients with ST-segment elevation myocardial infarction undergoing percutaneous coronary intervention

Guoyu Wang[1,2] ⓘ**, Ruzhu Wang[2], Ling Liu[2], Jing Wang[1,3] and Lei Zhou[1]**

Abstract

Objective: We aimed to determine whether the prognostic value of the shock index (SI) and its derivatives is better than that of the Thrombolysis In Myocardial Infarction risk index (TRI) for predicting adverse outcomes in patients with ST-segment elevation myocardial infarction (STEMI) undergoing primary percutaneous coronary intervention (PCI).

Methods: A total of 257 patients with STEMI undergoing primary PCI from January 2018 to June 2019 were analyzed in a retrospective cohort study. The SI, modified shock index (MSI), age SI (age × the SI), age MSI (age × the MSI), and TRI at admission were calculated. Clinical endpoints were in-hospital complications, including all-cause mortality, acute heart failure, cardiac shock, mechanical complications, re-infarction, and life-threatening arrhythmia.

Results: Multivariate analyses showed that a high SI, MSI, age SI, age MSI, and TRI at admission were associated with a significantly higher rate of in-hospital complications. The predictive value of the age SI and age MSI was comparable with that of the TRI (area under the receiver operating characteristic curve: $z = 1.313$ and $z = 0.882$, respectively) for predicting in-hospital complications.

[3]Department of Cardiology, The Affiliated Huaian No. 1 People's Hospital of Nanjing Medical University, Jiangsu Province, Huaian, China

[1]Department of Cardiology, The First Affiliated Hospital of Nanjing Medical University, Jiangsu Province, Nanjing, China
[2]Department of Cardiology, Taizhou People's Hospital, Jiangsu Province, Taizhou, China

Corresponding author:
Lei Zhou, Department of Cardiology, The First Affiliated Hospital of Nanjing Medical University, 300 Guangzhou Road, Nanjing, Jiangsu Province 210029, China.
Email: zhoulei@njmu.edu.cn.

Conclusions: The age SI and age MSI appear to be similar to the TRI for predicting in-hospital complications in patients with STEMI undergoing primary PCI.

Introduction

Acute ST-segment elevation myocardial infarction (STEMI) remains a leading cause of morbidity and mortality worldwide, despite advances in the fields of timely percutaneous coronary intervention (PCI) and optimal pharmacotherapy, as well as dedicated regional networks.[1,2] Therefore, early identification of these patients at high risk is crucial for aggressive clinical management and prognostic evaluation. Various risk scores have been developed and validated to obtain useful prognostic information in patients with STEMI. The Thrombolysis in Myocardial Infarction (TIMI) and the Global Registry of Acute Coronary Events (GRACE) are two widely used risk score systems, both of which have strong predictive values.[3,4] However, these systems are complicated and difficult to perform before emergent PCI. Moreover, patients bypassing the emergency room and transferring to the hospital for emergency PCI is inconvenient. Therefore, a simple risk score, which can be easily calculated in the prehospital setting and/or in the catheter laboratory, is crucial.

The TIMI risk index (TRI) is calculated using heart rate (HR), age, and systolic blood pressure (SBP). This index is readily assessable and was obtained from a cohort of patients enrolled in a thrombolysis trial.[5] The TRI has good predictive value for a large population of unselected patients with STEMI included in the National Registry of Myocardial Infarction-3 and -4 in the United States.[6] The shock index (SI), which is defined as the ratio of HR to systolic blood pressure, is used to predict mortality in patients with STEMI.[7–12] More recently, some derivatives of the SI, including the modified shock index (MSI), which is the ratio of HR to mean arterial pressure (MAP), the age SI (age × the SI) and the age MSI (age × the MSI) are used to predict an adverse prognosis in patients with STEMI.[11–14] All of these risk indices are composed of HR, age, and a parameter of blood pressure (SBP or MAP). Whether the age SI or age MSI is comparable, or even superior, to the TRI for predicting the prognosis of patients with STEMI has not yet been determined.

In this study, we aimed to apply these risk indices to predict the occurrence of in-hospital complications and compare the predictive power of these risk indices.

Methods

Study population

We retrospectively enrolled 374 consecutive patients who underwent emergency angiography at our hospital from January 2018 to June 2019. Primary PCI services were provided 24 hours a day, 7 days a week. Patients were either admitted from the community, or transferred from one of the satellite hospitals or from inpatient wards.

STEMI was defined using the current guidelines as follows:[15,16] (1) chest pain or equivalent symptoms lasting for longer than 30 minutes and (2) ST-segment elevation in at least two contiguous leads (at least 0.2 mV in men or at least 0.15 mV in women in leads V2–V3 and/or at least 0.1 mV in the other leads) or a new left bundle branch block. The exclusion criteria for this study were as follows: 1) patients with non-coronary artery disease; 2) patients with unstable angina or non-STEMI; and 3) patients with obvious arrhythmia at blood pressure and HR measurements. The study adhered to the Strengthening the Reporting of Observational Studies in Epidemiology statement.[17] Consent for treatment was obtained from all patients. Informed consent was waived because this was a retrospective study according to the institutional review board (Ethics Committee of Taizhou People's Hospital). The study protocol was approved by the Ethics Committee of Taizhou People's Hospital, Jiangsu Province, Taizhou, China (approval number: ZL201904).

Data collection and coronary angiography

The first electrocardiogram was performed as soon as possible, and biomarkers of cardiac necrosis (creatine kinase-MB and high-sensitivity troponin I) were determined immediately if patients were suspected of having acute coronary disease. When STEMI was confirmed, patients were administered 300 mg aspirin and 180 mg ticagrelor, and transferred to our catheter laboratory to receive emergent angiography. Before emergent angiography, SBP, diastolic blood pressure (DBP), and HR were measured in the supine position, and the Killip class was recorded in our catheter laboratory. After emergent intervention, patients were transferred to the coronary care unit for further management. Thereafter, baseline demographic characteristics and medical history were collected, relevant laboratory measurements were determined, and echocardiography was performed within 24 hours. Data on in-hospital adverse events were collected from the electronic medical history system.

Definitions and endpoints

The TRI was calculated using the following equation: $TRI = (HR \times [age/10]^2)/SBP$. The SI was defined as the ratio of HR to SBP. The MSI was defined as the ratio of HR and MAP ($MAP = SBP/3 + DBP \times 2/3$). The age SI was calculated as age multiplied by the SI and the age MSI was calculated as age multiplied by MSI. The ischemia time was defined as the time from symptom onset to a balloon crossing the occluded lesion. The primary endpoint was a composite outcome of in-hospital complications, including all-cause mortality, acute heart failure, cardiac shock, mechanical complications, re-infarction, and life-threatening arrhythmia.

Statistical analysis

Values are expressed as mean ± standard deviation for normally distributed continuous variables, as median (interquartile range) for non-normally distributed continuous variables, or as number and percentage for categorical variables. Normality of continuous variables was determined using the Kolmogorov–Smirnov test. The Student's t-test or Mann–Whitney U test was used to determine differences in continuous variables between groups with or without in-hospital complications as appropriate. The chi-square test was used to compare categorical variables between groups. Multivariate forward logistic regression analysis was used to identify the independent risk factors associated with in-hospital complications. Receiver operating characteristic (ROC) analyses were performed. The area under

the ROC curve (AUROC) was calculated to determine the predictive power of prognostic ability for in-hospital complications. The predictive performance of the SI, MSI, age SI, age MSI, and TRI at admission was compared using MedCalc software for Windows, version 19.0.7 (MedCalc Software, Mariakerke, Belgium). Results are expressed as odds ratios (ORs) with associated 95% confidence intervals (CIs). All tests were two-side, and the significance level was defined as $P < 0.05$. All statistical analyses were performed using IBM SPSS version 20 (IBM Corp., Armonk, NY, USA).

Results

Baseline characteristics of the study population

A total of 257 patients were enrolled in this study. The mean age of the study population was 63.77 ± 14.24 years, among which 77.4% (n = 199) were men. The mean TRI was 30.44 ± 16.29, and the median SI, MSI, age SI, and age MSI were 0.70 (0.55, 0.81), 0.89 (0.74, 1.06), 42.18 (31.97, 54.99), and 56.88 (42.54, 74.04), respectively. The detailed demographic and clinical characteristics are shown in Table 1.

Clinical outcomes

In the cohort, the incidence of in-hospital major complications and the type of complications are shown in Table 2.

Patients with in-hospital complications had a significantly higher SI, MSI, age SI, age MSI, and TRI than those without hospital complications (all $P < 0.001$, Figure 1). In multivariable analyses, a higher SI, MSI, age SI, age MSI, and TRI were significantly associated with a higher rate of in-hospital complications after adjusting for confounding factors (all $P < 0.01$, Table 3).

The AUROCs of the SI, MSI, age SI, age MSI, and TRI for predicting in-

hospital complications were 0.74 (95% CI 0.667–0.812), 0.743 (95% CI 0.671–0.815), 0.797 (95% CI 0.734–0.860), 0.792 (95% CI 0.727–0.856), and 0.780 (95% CI 0.712–0.849), respectively (Table 4, Figure 2). The cut-off values, sensitivity, and specificity for the SI, MSI, age SI, age MSI, and TRI for the prediction of in-hospital complications are shown in Table 4. The predictive value of the age SI was comparable with that of the TRI (AUROC: $z = 1.313$, $P = 0.19$), but superior to that of the SI (AUROC: $z = 2.055$, $P = 0.04$) and the MSI (AUROC: $z = 2.017$, $P = 0.044$) for predicting in-hospital complications. The predictive value of the age MSI was comparable with that of the TRI (AUROC: $z = 0.882$, $P = 0.38$), the SI (AUROC: $z = 1.732$, $P = 0.08$), and the MSI (AUROC: $z = 1.796$, $P = 0.07$) for predicting in-hospital complications (Figure 2).

Discussion

In this study, we evaluated and compared the predictive values of the SI, MSI, age SI, age MSI, and TRI at admission for in-hospital complications in patients with STEMI who received primary PCI. The main findings were as follows: (1) on admission, a high SI, MSI, age SI, age MSI, and TRI were independent predictors of in-hospital complications; (2) the predictive performance of the age SI and age MSI had the same predictive effect as that of the TRI for in-hospital complications.

The SI was initially developed for prediction of the hemodynamic state, and it is a reliable and easily assessable risk index for early shock in various disorders, such as trauma, hemorrhage, sepsis, and pulmonary embolism.[18] The predictive performance of the SI for the prognosis in patients with STEMI receiving PCI was first confirmed by Bilkova et al.[7] In their study, an SI ≥ 0.8 was found to be an independent predictor of in-hospital mortality

Table 1. Characteristics of the study population.

Variables	Total (n = 257)	No in-hospital complications (n = 197)	In-hospital complications (n = 60)	P value
Demographics				
Age (years)	63.77 ± 14.24	61.57 ± 13.99	71.00 ± 12.65	<0.01
Male sex	199 (77.4)	155 (78.68)	44 (73.33)	0.39
Body mass index (kg/m^2)	24.05 ± 3.82	24.35 ± 4.04	23.08 ± 2.79	0.02
Hypertension	165 (64.2)	128 (64.97)	37 (61.67)	0.64
Diabetes mellitus	96 (37.4)	69 (35.03)	27 (45.00)	0.17
Dyslipidemia	100 (38.9)	85 (43.15)	15 (25.00)	0.01
Current smoker	157 (61.1)	124 (62.94)	33 (55.00)	0.31
Previous PCI	10 (3.9)	7 (3.55)	3 (5.00)	0.61
Medical history				
ACEI/ARB	54 (21.01)	44 (22.34)	10 (16.67)	0.35
Beta-blocker	12 (4.67)	10 (5.08)	2 (3.33)	0.58
CCB	70 (27.24)	52 (26.40)	18 (30.00)	0.58
Hemodynamic and laboratory data				
Heart rate (beats/minute)	81.82 ± 14.88	79.26 ± 14.04	90.22 ± 14.57	<0.01
Systolic blood pressure (mmHg)	120.72 ± 23.24	123.61 ± 23.09	111.22 ± 21.27	<0.01
Diastolic blood pressure (mmHg)	76.39 ± 15.67	78.05 ± 15.73	70.95 ± 14.28	<0.01
Mean arterial pressure (mmHg)	91.17 ± 17.32	93.24 ± 17.29	84.37 ± 15.74	<0.01
Shock index	0.70 (0.55, 0.81)	0.66 (0.53, 0.75)	0.81 (0.70, 0.98)	<0.01
Modified shock index	0.89 (0.74, 1.06)	0.86 (0.71, 1.00)	1.04 (0.92, 1.13)	<0.01
Age shock index	42.18 (31.97, 54.99)	39 (30.87, 47.88)	60.17 (44.76, 71.33)	<0.01
Age modified shock index	56.88 (42.54, 74.04)	51.92 (39.54, 64.61)	77.79 (60.26, 90.54)	<0.01
TIMI risk index	30.44 ± 16.29	26.41 ± 13.34	43.69 ± 18.10	<0.01
Hemoglobin (g/L)	136.24 ± 22.22	138.96 ± 20.72	127.30 ± 24.69	<0.01
White blood cell count (×10^9/L)	10.48 ± 3.65	10.35 ± 3.66	10.91 ± 3.63	0.30
Cr (μmol/L)	67.50 (57.60, 79.95)	65.00 (54.75, 75.20)	77.75 (60.43, 99.60)	<0.01
HDL-C (mmol/L)	1.10 ± 0.34	1.08 ± 0.36	1.16 ± 0.27	0.11
LDL-C (mmol/L)	2.79 ± 0.85	2.85 ± 0.81	2.58 ± 0.95	0.03
UA (μmol/L)	339.12 ± 93.88	328.56 ± 81.29	373.79 ± 121.22	<0.01
Killip class ≥2 on admission	34 (13.2)	10 (5.08)	24 (40.00)	<0.01
Echocardiographic measurement				
LVEDD (mm)	50.83 ± 4.79	50.70 ± 4.86	51.25 ± 4.59	0.44
LVESD (mm)	33.30 ± 5.22	32.51 ± 4.96	35.90 ± 5.26	<0.01
LVEF (%)	59.95 (55, 66)	62 (58, 67)	52 (46, 60)	<0.01
Angiographic findings				
Infarction-related artery				
LAD	126 (49.0)	88 (44.67)	38 (63.33)	0.003
LCX	34 (13.2)	32 (16.24)	2 (3.33)	
RCA	94 (36.6)	77 (39.09)	17 (28.33)	
LM	3 (1.2)	1 (0.51)	2 (3.33)	
Multivessel disease	190 (73.9)	142 (72.08)	48 (80.00)	0.22
TIMI flow grade 0/1 on admission	192 (74.7)	144 (73.10)	48 (80.00)	0.28
TIMI flow grade 3 post PCI	209 (81.3)	169 (85.79)	40 (66.67)	<0.01
Ischemia time (minutes)	206.00 ± 90.00	205.37 ± 85.72	206.83 ± 102.17	0.91
Diameter of stent (mm)	3.00 (2.75, 3.50)	3.00 (2.75, 3.50)	3.00 (2.75, 3.00)	0.19
Length of stent (mm)	33 (24, 36)	33 (24, 36)	33(24, 36)	0.51
In-hospital medications				
Aspirin	253 (98.4)	196 (99.49)	57 (95.00)	0.01
Clopidogrel/ticagrelor	256 (99.7)	197 (100)	59 (98.33)	0.07

Table 1. Continued.

Variables	Total (n = 257)	No in-hospital complications (n = 197)	In-hospital complications (n = 60)	P value
Statins	253 (98.4)	194 (98.48)	59 (98.33)	0.94
ACEI/ARB	163 (63.4)	130 (65.99)	33 (55.00)	0.12
Beta-blocker	203 (79.0)	157 (79.70)	46 (76.67)	0.61
CCB	10 (3.9)	10 (5.08)	0 (0)	0.08

Data are mean ± standard deviation, n (%), or median (interquartile range).
PCI, percutaneous coronary intervention; ACEI, angiotensin-converting enzyme inhibitor; ARB, angiotensin receptor blocker; CCB, calcium channel blocker; TIMI, Thrombolysis In Myocardial Infarction; Cr, creatinine; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; UA, uric acid; LVEDD, left ventricular end-diastolic dimension; LVESD, left ventricular end-systolic dimension; LVEF, left ventricular ejection fraction; LAD, left anterior descending branch; LCX, left circumflex branch; RCA, right coronary artery; LM, left main coronary artery.
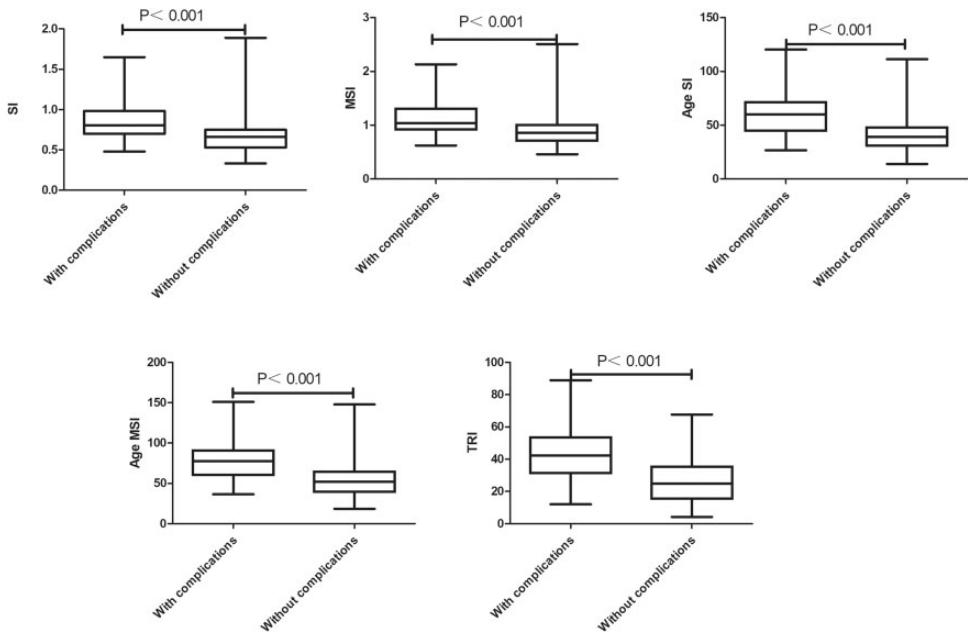
Table 2. Components of in-hospital complications.

Outcomes	All patients (n = 257)
In-hospital complications	60 (23.3)
All-cause mortality	5 (1.9)
Acute heart failure	41 (16.0)
Cardiac shock	9 (3.5)
Mechanical complications	4 (1.6)
Re-infarction	5 (1.9)
Life-threatening arrhythmia	17 (6.6)

Data are n (%).

in 644 patients. Subsequently, studies showed that a high SI was associated with short-term or/and long-term adverse events in patients with acute myocardial infarction (AMI).[8–10,18–25] Recently, the value of the SI in predicting cardiogenic shock that develops during primary PCI was shown in a study on 870 patients with STEMI who were hemodynamically stable before primary PCI.[23] Moreover, Hemradj et al. compared the predictive value of the SI with cardiac shock for 1-year mortality in 7412 consecutive patients with STEMI who were treated with primary PCI.[20] These authors found that the SI appeared to be a more sensitive prognostic predictor than cardiac shock. The SI has also been established as

a predictor of pronounced myocardial damage in patients with STEMI, as determined by cardiac magnetic resonance imaging in two studies.[9,22] The detailed pathophysiology underlying the association between a high SI and adverse outcomes has not been completely determined, but several possible explanations may be responsible. The SI is inversely correlated with physiological parameters, such as the cardiac index, stroke volume, left ventricular stroke work, and mean arterial pressure.[26] In the setting of AMI, sympathetic nerve activation arises, leading to an increase in HR and SBP, to compensate for the decreased cardiac out.[27] However, once preserved systolic ventricular function deteriorates owing to myocardial injury and ongoing ischemia, SBP decreases. Furthermore, the SI is mostly independent of the effects of pain and anxiety, which cause a concurrent rise in HR and SBP. This results in no change in the SI or even a decrease.[28] Shiraishi et al. showed that a low admission SBP of < 105 mmHg was associated with in-hospital death in 1475 Japanese patients with AMI who underwent primary PCI.[29] Additionally, a higher HR was independently associated with all-cause mortality and cardiovascular mortality in 22,398 patients who presented with AMI complicated by heart failure.[30] Therefore,

Figure 1. Comparison of the SI, MSI, age SI, age MSI, and TRI in patients with in-hospital complications and without complications.
SI, shock index; MSI, modified shock index; TRI, the Thrombolysis In Myocardial Infarction risk index.

Table 3. Effect of multiple variables on the incidence of in-hospital complications in univariate and multivariate analyses.

	Univariate analysis			Multivariate analysis		
Variables	OR	95% CI	P value	OR	95% CI	P value
SI	76.675	14.262–412.233	<0.001	18.099	2.360–138.826	0.005[a]
MSI	26.121	7.259–93.997	<0.001	10.854	2.189–53.823	0.004[b]
Age SI	1.067	1.045–1.090	<0.001	1.044	1.018–1.071	<0.001[c]
Age MSI	1.050	1.033–1.066	<0.001	1.037	1.017–1.057	<0.001[d]
TRI	1.072	1.048–1.095	<0.001	1.044	1.016–1.073	0.002[c]

OR, odds ratio; CI, confidence interval; SI, shock index; MSI, modified shock index; TRI, Thrombolysis In Myocardial Infarction risk index.
[a]Adjusted for Killip class ≥2 on admission, left anterior descending branch-related infarction, left ventricular ejection fraction, hemoglobin levels, and creatinine levels; [b]adjusted for Killip class ≥2 on admission, left anterior descending branch-related infarction, left ventricular ejection fraction, and hemoglobin levels; [c]adjusted for Killip class ≥2 on admission, left anterior descending branch-related infarction, left ventricular ejection fraction, and creatinine levels; [d]adjusted for Killip class ≥2 on admission, left anterior descending branch-related infarction, and left ventricular ejection fraction.

high HR and low SBP have been included in some risk models.[3,4] The SI, which integrates these two parameters into one index, should be a more sensitive indicator of left ventricular dysfunction and hemodynamic instability.

The MSI, which is defined as the ratio of HR and MAP, is a better prognostic

Table 4. Diagnostic capability assessment of five shock risk indices.

	Cutoff value	Sensitivity (%)	Specificity (%)	AUROC
SI	0.785	55.0	80.2	0.740
MSI	0.965	66.7	72.1	0.743
Age SI	46.125	75.0	72.6	0.797
Age MSI	70.78	66.7	82.7	0.792
TRI	38.84	63.3	83.8	0.780

AUROC, area under the receiver operating characteristic curve; SI, shock index; MSI, modified shock index; TRI, Thrombolysis In Myocardial Infarction risk index.
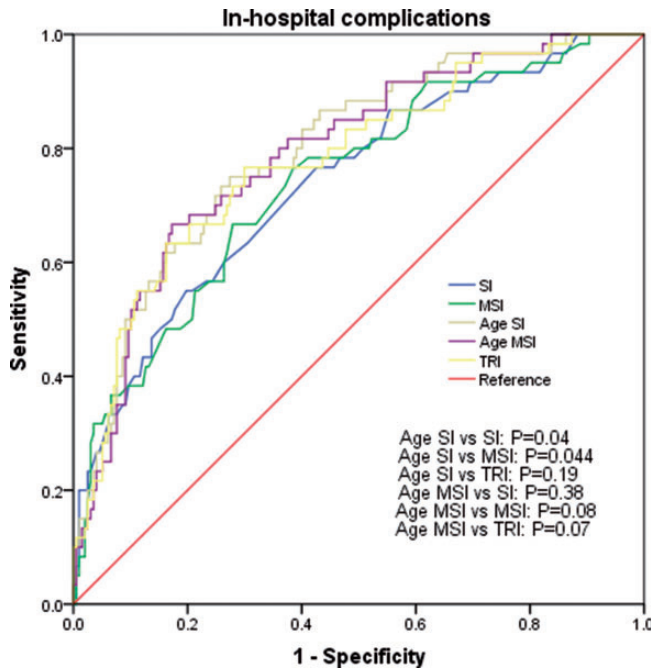
Figure 2. Receiver operating characteristics curves of the SI, MSI, age SI, age MSI, and TRI for predicting in-hospital complications.
SI, shock index; MSI, modified shock index; TRI, Thrombolysis In Myocardial Infarction risk index.

predictor than the SI in the setting of trauma.[31] Theoretically, MAP, which combines information of SBP and SDP, is determined by cardiac output and peripheral vascular resistance. Low MAP is more suggestive of decreased cardiac output rather than reduced peripheral vascular resistance in the setting of AMI, especially complicated by heart failure or cardiac shock, and represents depressed myocardial perfusion.[32] Shiraishi et al. found that at admission, a low MAP of $< 79 \, \text{mmHg}$ might be associated with in-hospital mortality in 1413 patients with primary PCI treatment.[32] Some studies compared the prognostic ability of the MSI and SI in patients with AMI. Shangguan et al. found that the MSI may be more accurate

than the SI in predicting all-cause mortality and major adverse cardiovascular events within 7 days in 160 patients with STEMI who received emergent PCI.[14] However, the accuracy of the MSI for predicting major adverse cardiovascular events, death, re-infarction or heart failure in STEMI with 1 year was found to be comparable with that of the SI in a study conducted by Reinstadler et al.[9] The present study showed that the MSI was an independent predictor for in-hospital complications, which is consistent with previous studies.[12]

Age is widely accepted as an important predictor of outcome in patients with acute coronary syndrome.[33] Therefore, age is integrated into various risk score systems for elderly patients who are characterized by a high frequency of comorbidities and frailty.[4] Addition of age to the SI or the MSI is supposed to provide a better discriminative ability to identify high-risk patients. Yu et al. showed that the age SI was comparable with the GRACE score, but superior to the SI and MSI for predicting all-cause mortality in patients with AMI who underwent PCI.[11] More recently, Zhou et al. further confirmed this result and also found that the age MSI was an independent predictor of adverse outcomes in patients with STEMI who underwent emergent PCI.[12] In their study, the predictive value of the age MSI was comparable with that of the GRACE score and better than that of the SI and MSI for in-hospital cardiovascular events, and 6-month and long-term all-cause mortality. Similar results were obtained in our study, which showed that the age SI and age MSI were independently associated with in-hospital complications.

The TRI, which is an integration of SBP, HR, and age, is also a valid clinical tool for identifying high-risk patients with STEMI. Initially, the TRI was developed for risk assessment of in-hospital and 30-day mortality.[5] In the TIMI 2 trial, which enrolled 3153 patients with STEMI, an increase in the TRI was also associated with elevated long-term

mortality and heart failure.[34] The prognostic predictive value of the TRI was extended to patients with acute coronary syndrome in a single-center cohort study of 710 unselected patients with acute coronary syndrome.[35] Actually, the TRI formula can be considered as a combination of the SI with the variable age $(\text{TRI} = \text{SI} \times (\text{age}/10)^2)$. Therefore, the TRI is similar to the age SI and age MSI. Consequently, we speculated that the age SI or age MSI is comparable with, or even better than, the TRI in predicting the prognosis of patients with STEMI. As anticipated, in the current study, the age SI and age MSI were comparable with the TRI in predicting in-hospital complications in patients with STEMI who were treated with primary PCI. Accordingly, both the age SI and age MSI can function as the TRI to rapidly identify high-risk patients with STEMI upon admission, or even in the ambulance, without using the medical history, laboratory measurements, or a complex integer point scale system.

Several limitations should be considered in this study. First, this was a retrospective, observational study performed in a single center, and a relatively small number of patients were enrolled in this study. Therefore, potential confounding factors and selection bias could not be completely avoided. Second, measurements of HR and blood pressure were performed at just one time point and blood pressure was measured non-invasively.

In conclusion, the SI, MSI, age SI, age MSI, and TRI at admission are independent predictors of in-hospital complications in patients with STEMI undergoing primary PCI. The age SI and age MSI appear to be similar to the TRI at admission for predicting in-hospital complications in patients with STEMI undergoing primary PCI.

Declaration of conflicting interest

The authors declare that there is no conflict of interest.

Author contributions

Lei Zhou designed the study and supervised data collection. Guoyu Wang and Ruzhu Wang collected the primary data and drafted the initial manuscript. Ling Liu and Jing Wang helped with data analyses. All authors contributed to discussions and critically appraised the manuscript.

ORCID iD

Guoyu Wang ⓘ https://orcid.org/0000-0003-1343-1187

References

1. Buccheri S, Capranzano P, Condorelli A, et al. Risk stratification after ST-segment elevation myocardial infarction. *Expert Rev Cardiovasc Ther* 2016; 14: 1349–1360. 2016/11/08. DOI: 10.1080/14779072.2017.1256201.
2. Vicent L, Velasquez-Rodriguez J, Valero-Masa MJ, et al. Predictors of high Killip class after ST segment elevation myocardial infarction in the era of primary reperfusion. *Int J Cardiol* 2017; 248: 46–50. 2017/09/26. DOI: 10.1016/j.ijcard.2017.07.038.
3. Garcia-Paredes T, Aguilar-Alonso E, Arboleda-Sanchez JA, et al. Evaluation of prognostic scale thrombolysis in myocardial infarction and Killip. An ST-elevation myocardial infarction new scale. *Am J Emerg Med* 2014; 32: 1364–1369. 2014/09/17. DOI: 10.1016/j.ajem.2014.08.026.
4. Fujii T, Suzuki T, Torii S, et al. Diagnostic accuracy of Global Registry of Acute Coronary Events (GRACE) risk score in ST-elevation myocardial infarction for in-hospital and 360-day mortality in Japanese patients. *Circ J* 2014; 78: 2950–2954. 2014/10/07. DOI: 10.1253/circj.cj-14-0808.
5. Morrow DA, Antman EM, Giugliano RP, et al. A simple risk index for rapid initial triage of patients with ST-elevation myocardial infarction: an InTIME II substudy. *Lancet* 2001; 358: 1571–1575. 2001/11/22. DOI: 10.1016/s0140-6736(01)06649-1.
6. Wiviott SD, Morrow DA, Frederick PD, et al. Performance of the thrombolysis in myocardial infarction risk index in the National Registry of Myocardial Infarction-3 and -4: a simple index that predicts mortality in ST-segment elevation myocardial infarction. *J Am Coll Cardiol* 2004; 44: 783–789. 2004/08/18. DOI: 10.1016/j.jacc.2004.05.045.
7. Bilkova D, Motovska Z, Widimsky P, et al. Shock index: a simple clinical parameter for quick mortality risk assessment in acute myocardial infarction. *Can J Cardiol* 2011; 27: 739–742. 2011/09/29. DOI: 10.1016/j.cjca.2011.07.008.
8. Kobayashi A, Misumida N, Luger D, et al. Shock Index as a predictor for In-hospital mortality in patients with non-ST-segment elevation myocardial infarction. *Cardiovasc Revasc Med* 2016; 17: 225–228. 2016/03/15. DOI: 10.1016/j.carrev.2016.02.015.
9. Reinstadler SJ, Fuernau G, Eitel C, et al. Shock index as a predictor of myocardial damage and clinical outcome in ST-elevation myocardial infarction. *Circ J* 2016; 80: 924–930. 2016/02/24. DOI: 10.1253/circj.CJ-15-1135.
10. Spyridopoulos I, Noman A, Ahmed JM, et al. Shock-index as a novel predictor of long-term outcome following primary percutaneous coronary intervention. *Eur Heart J Acute Cardiovasc Care* 2015; 4: 270–277. 2014/11/27. DOI: 10.1177/2048872614561480.
11. Yu T, Tian C, Song J, et al. Age shock index is superior to shock index and modified shock index for predicting long-term prognosis in acute myocardial infarction. *Shock* 2017; 48: 545–550. 2017/05/10. DOI: 10.1097/shk.0000000000000892.
12. Zhou J, Shan PR, Xie QL, et al. Age shock index and age-modified shock index are strong predictors of outcomes in ST-segment elevation myocardial infarction patients undergoing emergency percutaneous coronary intervention. *Coron Artery Dis* 2019; 30: 398–405. 2019/06/18. DOI: 10.1097/mca.0000000000000759.

13. Abreu G, Azevedo P, Galvao Braga C, et al. Modified shock index: a bedside clinical index for risk assessment of ST-segment elevation myocardial infarction at presentation. *Rev Port Cardiol* 2018; 37: 481–488. 2018/05/29. DOI: 10.1016/j.repc.2017.07.018.

14. Shangguan Q, Xu JS, Su H, et al. Modified shock index is a predictor for 7-day outcomes in patients with STEMI. *Am J Emerg Med* 2015; 33: 1072–1075. 2015/05/20. DOI: 10.1016/j.ajem.2015.04.066.

15. Ibanez B, James S, Agewall S, et al. 2017 ESC Guidelines for the management of acute myocardial infarction in patients presenting with ST-segment elevation: the task force for the management of acute myocardial infarction in patients presenting with ST-segment elevation of the European Society of Cardiology (ESC). *Eur Heart J* 2018; 39: 119–177. 2017/09/10. DOI: 10.1093/eurheartj/ehx393.

16. Levine GN, Bates ER, Blankenship JC, et al. 2015 ACC/AHA/SCAI Focused update on primary percutaneous coronary intervention for patients with ST-elevation myocardial infarction: an update of the 2011 ACCF/AHA/SCAI guideline for percutaneous coronary intervention and the 2013 ACCF/AHA guideline for the management of ST-elevation myocardial infarction. *J Am Coll Cardiol* 2016; 67: 1235–1250. 2015/10/27. DOI: 10.1016/j.jacc.2015.10.005.

17. Sharp M, Bertizzolo L, Rius R, et al. Using the STROBE statement: survey findings emphasized the role of journals in enforcing reporting guidelines. *J Clin Epidemiol* 2019; 116: 26–35. DOI: 10.1016/j.jclinepi.2019.07.019.

18. Koch E, Lovett S, Nghiem T, et al. Shock index in the emergency department: utility and limitations. *Open Access Emerg Med* 2019; 11: 179–199. 2019/10/17. DOI: 10.2147/oaem.S178358.

19. Abe N, Miura T, Miyashita Y, et al. Long-term prognostic implications of the admission shock index in patients with acute myocardial infarction who received percutaneous coronary intervention. *Angiology* 2017; 68: 339–345. 2016/06/16. DOI: 10.1177/0003319716653885.

20. Hemradj VV, Ottervanger JP, de Boer MJ, et al. Shock index more sensitive than cardiogenic shock in ST-elevation myocardial infarction treated by primary percutaneous coronary intervention. *Circ J* 2017; 81: 199–205. 2016/12/17. DOI: 10.1253/circj.CJ-16-0616.

21. Huang B, Yang Y, Zhu J, et al. Usefulness of the admission shock index for predicting short-term outcomes in patients with ST-segment elevation myocardial infarction. *Am J Cardiol* 2014; 114: 1315–1321. 2014/09/10. DOI: 10.1016/j.amjcard.2014.07.062.

22. Hwang JK, Jang WJ, Song YB, et al. Shock index as a predictor of myocardial injury in ST-segment elevation myocardial infarction. *Am J Med Sci* 2016; 352: 574–581. 2016/12/06. DOI: 10.1016/j.amjms.2016.09.003.

23. Wei Z, Bai J, Dai Q, et al. The value of shock index in prediction of cardiogenic shock developed during primary percutaneous coronary intervention. *BMC Cardiovasc Disord* 2018; 18: 188. 2018/10/05. DOI: 10.1186/s12872-018-0924-z.

24. Zarzaur BL, Croce MA, Fischer PE, et al. New vitals after injury: shock index for the young and age x shock index for the old. *J Surg Res* 2008; 147: 229–236. 2008/05/24. DOI: 10.1016/j.jss.2008.03.025.

25. Zhang X, Wang Z, Wang Z, et al. The prognostic value of shock index for the outcomes of acute myocardial infarction patients: a systematic review and meta-analysis. *Medicine (Baltimore)* 2017; 96: e8014. 2017/09/21. DOI: 10.1097/md.0000000000008014.

26. Rady MY, Nightingale P, Little RA, et al. Shock index: a re-evaluation in acute circulatory failure. *Resuscitation* 1992; 23: 227–234. 1992/06/01. DOI: 10.1016/0300-9572(92)90006-x.

27. Graham LN, Smith PA, Stoker JB, et al. Sympathetic neural hyperactivity and its normalization following unstable angina and acute myocardial infarction. *Clin Sci (Lond)* 2004; 106: 605–611. 2004/02/05. DOI: 10.1042/cs20030376.

28. Keller AS, Kirkland LL, Rajasekaran SY, et al. Unplanned transfers to the intensive care unit: the role of the shock index. *J Hosp Med* 2010; 5: 460–465.

29. Shiraishi J, Kohno Y, Sawada T, et al. Prognostic impact of systolic blood pressure at admission on in-hospital outcome after primary percutaneous coronary intervention for acute myocardial infarction. *J Cardiol* 2012; 60: 139–144. 2012/04/24. DOI: 10.1016/j.jjcc.2012.02.008.

30. Dobre D, Kjekshus J, Rossignol P, et al. Heart rate, pulse pressure and mortality in patients with myocardial infarction complicated by heart failure. *Int J Cardiol* 2018; 271: 181–185. 2018/09/19. DOI: 10.1016/j.ijcard.2018.05.017.

31. Singh A, Ali S, Agarwal A, et al. Correlation of shock index and modified shock index with the outcome of adult trauma patients: a prospective study of 9860 patients. *N Am J Med Sci* 2014; 6: 450–452.

32. Shiraishi J, Nakamura T, Shikuma A, et al. Relationship between mean blood pressure at admission and in-hospital outcome after primary percutaneous coronary intervention for acute myocardial infarction. *Int Heart J* 2016; 57: 547–552. 2016/08/19. DOI: 10.1536/ihj.15-480.

33. Turk J, Fourny M, Yayehd K, et al. Age-related differences in reperfusion therapy and outcomes for ST-segment elevation myocardial infarction. *J Am Geriatr Soc* 2018; 66: 1325–1331. 2018/04/24. DOI: 10.1111/jgs.15383.

34. Truong QA, Cannon CP, Zakai NA, et al. Thrombolysis in Myocardial Infarction (TIMI) Risk Index predicts long-term mortality and heart failure in patients with ST-elevation myocardial infarction in the TIMI 2 clinical trial. *Am Heart J* 2009; 157: 673–679.e671. 2009/04/01. DOI: 10.1016/j.ahj.2008.12.010.

35. Ilkhanoff L, O'Donnell CJ, Camargo CA, et al. Usefulness of the TIMI Risk Index in predicting short- and long-term mortality in patients with acute coronary syndromes. *Am J Cardiol* 2005; 96: 773–777. 2005/09/20. DOI: 10.1016/j.amjcard.2005.04.059.