Modified Shock Index as Clinical Predictor of In-Hospital Outcomes in Cases of Acute Coronary Syndrome: A Retrospective Cohort Study

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Abstract

Background. In the Philippines, Acute Coronary Syndrome (ACS) is a major cause of mortality. Recognizing high-risk ACS patients quickly is crucial. The Modified Shock Index (MSI), a concise bedside risk scoring system, may enhance triaging by predicting short-term outcomes, facilitating a more aggressive approach for timely intervention.

Objectives. The aim of this study is to determine MSI's predictive value for in-hospital mortality in ACS patients, comparing its sensitivity and specificity to Thrombolysis In Myocardial Infarction (TIMI) risk scoring. It also intends to determine association between MSI and major adverse cardiovascular events (MACE).

Methods. This retrospective cohort study was conducted in a tertiary hospital with 172 patients aged 18 and above admitted for ACS from January 2017 to December 2022, focused on in-hospital mortality as the primary outcome and other MACE as secondary outcomes. Chi-square test customized for multiple response sets was done to determine association between MSI and clinical outcomes. The study employed ROC analysis for MSI, generating a curve to illustrate sensitivity-specificity trade-offs, Youden Index determined to identify optimal cut-off points, and DeLong's test to compare efficacy of MSI and TIMI.

Results. A high MSI (≥1) was significantly and independently linked to in-hospital all-cause mortality in ACS patients ($p < 0.001$). MSI exhibits 82.35% sensitivity and 82.89% specificity for predicting in-hospital mortality. Chi-square test customized for multiple response sets revealed statistically significant association between MSI and the occurrences of cardiogenic shock, revascularization, life-threatening arrhythmia, and cardiac arrest. ROC analysis reveals MSI and TIMI scores as strong predictors (AUC values: 0.848 and 0.787 respectively), with comparable performance indicated by the DeLong test.

Conclusion. MSI proved a reliable parameter for predicting in-hospital mortality in patients presenting with ACS in Notre Dame de Chartres Hospital.

Keywords: Acute Coronary Syndrome, Modified Shock Index, Scoring system, Major adverse cardiovascular events

Introduction

Globally, cardiovascular disease is still among the leading causes of mortality, and ischemic heart disease remains the most prevalent.[1] Among these cases, > 75% come from low and middle-income countries.[2] Moreover, ischemic heart disease remains one of the top causes of death in the Philippines, comprising 17.9% of the total deaths from January to November 2021.[3] Early risk assessment aided by scoring systems of patients upon diagnosis of Acute Coronary Syndrome (ACS), therefore, is essential for prognostication and the subsequent need for more aggressive management of this vulnerable population. Incorporating these risk stratification models into the management of patients admitted for ACS have been recommended in several guidelines.[4-6] The Thrombolysis in Myocardial Infarction (TIMI) risk scoring and the more recent Global Registry of Acute Coronary Events (GRACE), are scoring systems with strong predictive values that are already widely used in prognostication and risk stratification of all ACS patients. However, the Modified Shock Index (MSI) is less time-consuming with fewer variables incorporated, and could be easily utilized in the Emergency Department in the prediction of short-term outcomes of ACS patients. This could be valuable in readily assisting physicians in

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evaluating patients in need of immediate invasive strategies in this population.

The MSI is a known predictor of hemodynamic instability already widely used in trauma and emergency patients.[7,8] The MSI, which is the ratio of the cardiac rate and Mean Arterial Pressure (MAP), is a fast and simple scoring system. Unlike other scoring tools, it is independent of diagnostic parameters and other subjective data.[9] Several studies have reported that MAP is an independent predictor of in-hospital mortality for cardiac patients.[10] The MSI, which relies on MAP, was recently used in evaluating outcomes in ACS patients. An observational study conducted by Yu et al. in 2017 involving 2,631 ACS patients who underwent PCI, reported that the Shock Index (SI), defined as the cardiac rate divided by systolic blood pressure), and the GRACE score showed similar performance in predicting all-cause mortality.[11]

However, a study conducted by Shangguan et al. in 2015 compared predictive values of the Shock Index (SI) and the more recently used MSI for 7-day outcomes in patients with STEMI, with the result of MSI even being more accurate than SI.[12] In a separate study by Chiang et al in 2022 involving 1,552 STEMI patients, they also reported that MSI had a better predictive value than SI for mortality.[13] Moreover in a more recent study conducted by Schmitz et al. in 2022, they also concluded that MSI had a better predictive value than SI regarding long-term MACE development in both STEMI and non-STEMI cases.[14] These could be attributed to the MSI incorporating MAP into the equation, which better assesses myocardial perfusion and systemic vascular resistance.[15]

This research therefore aims to assess the predictive value of MSI in predicting in-hospital mortality of ACS patients admitted at a tertiary hospital, which to our knowledge after extensive use of academic search engines (e.g. PubMed, Google Scholar, HERDIN) is the first study to evaluate the use of MSI in predicting in-hospital mortality in overall ACS population admitted for ACS in the Philippines.

General objective: To evaluate the predictive value of the Modified Shock Index (MSI) for in-hospital mortality of patients admitted for Acute Coronary Syndrome in Notre Dame de Chartres Hospital.

Specific objectives:

1. To determine the sensitivity and specificity of MSI in determining in-hospital mortality.
2. To evaluate association of MSI and the occurrence of in-hospital MACE (i.e. cardiogenic shock, revascularization, life-threatening arrhythmia, arrest) of patients admitted for ACS.
3. To compare the sensitivity and specificity of MSI with the more widely used and established risk scoring system TIMI in predicting in-hospital mortality of patients admitted due to ACS in NDCH.

Methods

Study Design, Setting and Participants. This is a single-centered retrospective cohort study involving all patients admitted due to Acute Coronary Syndrome (ACS) hospitalized at Notre Dame de Chartres Hospital between January 2017 and December 2022.

Inclusion Criteria. Patients were included if they met the following:

1. At least 18 years of age
2. They were admitted to NDCH with a diagnosis of Acute Coronary Syndrome
3. They had a heart rate and mean arterial pressure that were measured upon admission at the emergency department;
4. Course was followed for at least 24 hours, unless classified under mortality after admission

Exclusion Criteria: Patients were excluded if they had any of the following conditions:

1. Patients 17 years old and below
2. Acute Coronary Syndrome precipitated by trauma
3. Missing MSI-related data from patient's records;
4. They were transferred to another hospital within 24 hours of admission.

Study Size. This study involved all patients 18 years old and above admitted for Acute Coronary Syndrome (ACS) at Notre Dame de Chartres Hospital between January 2017 and December 2022, with a total of 173 patients. However, this study only utilized an eligible sample size of 169 due to charts excluded due to missing data.

Data Collection. Data gathering was done primarily through chart review of patients who meet the predefined criteria, with obtained consent from the institution. General/baseline data of eligible patients were gathered, namely age, sex, smoking history, and risk factors for ACS present (Hypertension, Diabetes Mellitus, Family history of cardiac disease/CAD/Myocardial infarction, and obesity).

ACS patients admitted were classified into ST-elevation myocardial infarction (STEMI), non-ST-elevation myocardial infarction (NSTEMI), and Unstable angina (UA) as defined by the European Society of Cardiology (ESC) 2023 guidelines criteria, (i.e. STEMI as having symptoms of ACS, with the presence of biomarker elevation and significant persistent ST-elevation on 12-Lead ECG; NSTEMI as having symptoms of ACS with biomarker elevation, but without ECG changes consistent with STEMI; UA as prolonged angina at rest/new onset of severe angina/angina that is increasing in frequency, longer in duration, or lower in threshold, without an elevated biomarker level).

The TIMI score of study subjects upon admission were noted. The Modified Shock Index (MSI) of all these patients upon admission was calculated as the ratio of heart rate (HR) and mean arterial pressure (MAP). Study subjects were then classified into two groups, those with high MSI (≥ 1) and low MSI (<1) score.

Figure 1 depicts the conceptual framework.

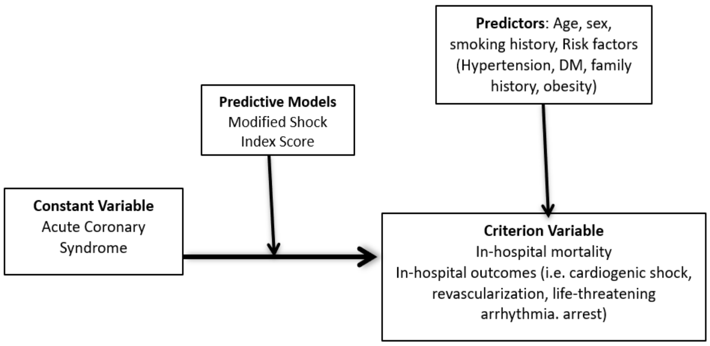

Figure 1. Conceptual Framework

Outcome Measures. The primary outcome of this study was in-hospital mortality, and secondary outcome were in-hospital MACE namely cardiogenic shock, revascularization, life-threatening arrhythmia, and arrest. Statistical analyses were accomplished using SPSS V25.0. (IBM Corp., Armonk, NY, United States)

Statistical Analysis. Several steps were conducted to evaluate the parameters.

Sensitivity and specificity of MSI in determining MACE. The sensitivity, specificity, positive predictive value, and negative predictive value of MSI were calculated. ROC analysis for MSI was performed, and ROC curve generated to visualize the trade-off between sensitivity and specificity. The area under the ROC curve (AUC) was calculated, to provide a summary measure of diagnostic accuracy. In addition, optimal cutoff point on the ROC curve (Youden Index) that maximizes sensitivity and specificity was identified, and Metric score evaluated.

Compare the sensitivity and specificity of MSI with the TIMI risk scoring system. The sensitivity, specificity, positive predictive value, and negative predictive value for both MSI and TIMI were calculated. DeLong's Test was used to assess the comparative performance of MSI and TIMI.

Determine the demographic profile of patients admitted for Acute Coronary Syndrome. In the context of descriptive statistics, categorical data were examined through cross-tabulation. Instances featuring non-mutually exclusive responses, exemplified by the amalgamation of Risk Factors for ACS and In-hospital outcomes, were treated as distinct multiple-response sets within the cross-tabulations. Numerical variables were subjected to analysis utilizing the mean and standard deviation.

*Determine the association between demographic data and MSI***.** Proportions of in-hospital mortality within different demographic categories were calculated. Stratified descriptive statistics was done for each demographic variable (e.g., mean age for patients with and without in-hospital mortality). To ascertain significant disparities between patients with MSI $\geq$ 1 and those with MSI < 1 concerning categorical variables, Chi-square tests of Independence were employed. Notably, multiple-response sets were subjected to scrutiny using a tailored Chi-Square independence test specifically designed for such scenarios. Concurrently, for numerical variables, a *t-test* for independent groups was executed for the purpose of discerning significant differences between the groups. All statistical tests adhered to a significance level of $p < 0.05$.

Ethical Considerations. The research protocol was submitted and approved by the Baguio General Hospital Medical Center Research Ethics Committee. Number codes were utilized and no patient names were used in this study to maintain confidentiality. Encoded data were saved in a password-protected file. There is no conflict of interest in any form in the conduct of this study. No other funders involved in this study.

Definition of Terms.

1. *Acute Coronary Syndrome (ACS)* – Refers to the constellation of signs and symptoms resulting from insufficient flow through the coronary arteries, and encompass Acute Myocardial Ischemia (STEMI and NSTEMI) and Unstable Angina.[4]
2. *Revascularization* – Refers to blood supply restoration to the ischemic myocardium to limit ongoing injury/necrosis and improve outcomes, and encompass fibrinolysis, percutaneous coronary intervention, and Coronary Artery Bypass Grafting.[5]
3. *Mean arterial pressure (MAP)* - Average arterial pressure throughout one cardiac cycle, influenced by cardiac output and systemic vascular resistance, calculated as [(2x DBP) + SBP]/3.[16]
4. *Mortality* - defined as patients with who died in the hospital before discharge regardless of the cause of death

Results

Table I provides an overview of the baseline characteristics of patients, focusing on their MSI scores, along with pertinent test statistics and p-values. The MSI scores, distinguished between those ≥1 and <1, exhibit mean ($\pm$ SD) values of 1.40 (0.46) and 0.74 (0.15), respectively, and with an overall mean MSI score of 0.89 (0.38). The subsequent analysis of demographic and clinical variables unfolds with considerations for age, sex, BMI, height, weight, smoking status, risk factors for ACS, ACS type, and in-hospital outcomes.

The mean age for patients with MSI ≥1 is 59.03 ($\pm$16.15), compared to 58.34 ($\pm$11.40) for those with MSI < 1, with an overall mean age of 58.50 ($\pm$12.63). A *t-test* for independent groups indicates no significant age difference between the two MSI groups ($p = 0.766$). Sex distribution does not vary significantly between the MSI

Table I. Patient Baseline Characteristics and MSI score

Variable	Modified Shock Index (MSI) Score ≥1 (n=40) 1.40 (0.46)	< 1 (n=129) 0.74 (0.15)	Total 0.89 (0.38	p-value
Age (years)	59.03 (16.15)	58.34 (11.40)	58.50 (12.63)	0.766
Sex				0.117
Male	25	9	122	
Female	15	32	47	
BMI	25.59 (5.12)	26.15 (3.65)	26.02 (4.04)	0.52
Height (cm)	160.55 (7.89)	161.64 (7.83)	161.38 (7.83)	0.442
Weight kg)	66.35 (16.02)	68.43 (11.34)	67.94 (12.58)	0.446
Smoking Status				0.888
Smoker/Previous Smoker	16	50	66	
Non-smoker	24	79	103	
Risk Factors for ACS				0.806
Hypertension	26	9	122	
DM Type 2	13	40	53	
Dyslipidemia	19	77	76	
Family history of CAD	18	63	81	
ACS Type				0.442
STEMI	31	96	127	
NSTEMI	7	18	25	
Unstable Angina	2	15	17	
Hemodynamics				
SBP	92.45 (22.62)	130.15 (23.09)	121 (27.98)	*0.000***
DBP	58.05 (19.78)	84.81 (14.15)	78.47 (19.32)	*0.000****
MAP	69.52 (19.93)	99.92 (15.75)	92.72(21.19)	*0.000****
Heart Rate	93.00 (26.23)	73.16 (17.41)	77.86 (21.50)	*0.000****
TIMI	6.08 (3.48)	3.36 (2.03)	4.01 (2.70)	*0.000****

****p<0.001*

Table II. Relationship of MSI score and Clinical Outcomes

In-Hospital Outcome	MSI Sensitivity	MSI Specificity	TIMI Sensitivity	TIMI Specificity
Mortality	82.35%	82.89%	70.59%	81.58%
Cardiogenic Shock	75.76%	88.97%	75.76%	62.5%
Revascularization	95.42%	18.75%	33.99%	81.25%
Life-threatening Arrhythmia	54.35%	87.80%	43.48%	83.74%
Arrest	72.22%	92.82%	72.22%	82.12%

Table III. Summary of Specificity and Sensitivity of MSI and TIMI in predicting in-hospital Outcomes

Variable	MSI Score ≥ 1 (n=40) 1.40 (± 0.46)	< 1 (n=129) 0.74 (± 0.15)	Total 0.89 (± 0.38)	p Value (chi-square)
Mortality	14	3	17	0.000***
Cardiogenic Shock	25	8	33	
Revascularization	33	120	153	
Life-threatening Arrhythmia	25	21	46	
Arrest	15	3	18	

**** p < 0.001*

≥ 1 and MSI < 1 groups, as revealed by the chi-square test (*p = 0.117*). Further scrutiny of BMI, height, weight, smoking status, risk factors for ACS, and ACS type are detailed in *Table I*, with no statistically significant differences detected.

The analysis of hemodynamics between the MSI ≥ 1 and MSI < 1 groups reveal significant directional differences. Patients with MSI ≥ 1 exhibit lower Systolic Blood Pressure (*p < 0.001*), lower Diastolic Blood Pressure (*p < 0.001*), and lower Mean Arterial Pressure (*p < 0.001*) compared to those with MSI<1. Conversely, the Heart Rate is higher in the MSI≥1 group (t = 4.486, p < .001). Additionally, the TIMI score, indicative of the severity of coronary artery disease, is significantly higher in the MSI≥1 group (t = 4.683, p < .001).

The analysis, employing a Chi-square test customized for multiple response sets, focused on the relationship between Modified Shock Index (MSI) scores and specific clinical outcomes. The results indicate a statistically significant association between MSI scores and the occurrences of Mortality ($\chi2$=177.281, p < .001), Cardiogenic Shock, Revascularization, Life-threatening

Arrhythmia, and Arrest.

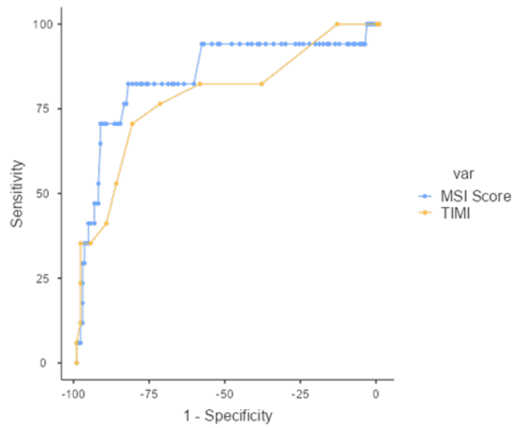

Figure 1 Combined ROC Curves for MSI and TIMI in predicting In-hospital Mortality

The cross-tabulation analysis between Modified Shock Index Classification (MSIC) and clinical outcomes reveals distinct directional differences. Patients with MSI≥1 exhibit significantly higher rates of mortality (82.4% vs. 17.6% of 17 recorded cases), cardiogenic shock (75.8% vs. 24.2% of 33 recorded cases), and arrhythmia (54.3% vs. 45.7% of 46 recorded cases) compared to those with MSI<1. Notably, revascularization is more frequently observed in patients with MSI≥1 (83.3% of 161) compared to MSI<1 (16.7% of 161).

Comparing Sensitivity and Specificity of MSI and TIMI in Predicting In-hospital Outcomes. The analysis compared the predictive efficacy of the MSI and TIMI scores in predicting mortality, utilizing various cutoff points. The Youden Index, a measure of the balance between sensitivity and specificity, was employed to identify optimal cutoff points. Additionally, DeLong's Test was used to assess the comparative performance of MSI and TIMI.

Predicting In-hospital Mortality. For the MSI scale, a comprehensive examination spans cutoff points ranging from 0.31 to 3.03. The Youden Index, spanning from 0 to 0.652, consistently aligns with an Area Under the Curve (AUC) of 0.848. Remarkably, the optimal cutoff point surfaces at 1.02, affording 82.35% sensitivity and 82.89% specificity. This yields a harmonized metric score of 1.652, where true positives tally to 14, true negatives amount to 126, false negatives stand at 3, and false positives are 26.

In contrast, the TIMI scale undergoes scrutiny across a spectrum of cutoff points from 1 to 14. The Youden Index fluctuates from 0 to 0.521, with a consistent AUC of 0.787. The optimal cutoff point emerges at 7, signifying 70.59% sensitivity and 81.58% specificity. This equates to a metric score of 1.52, featuring 12 true positives, 124 true negatives, 28 false positives, and 5 false negatives.

As seen in Figure 1, the ROC curve visually encapsulates the sensitivity-specificity trade-off for both scales. While a visual inspection suggests higher accuracy for MSI in predicting mortality, the DeLong Test of Difference between Areas Under the Curve (AUCs) reveals non-significant AUC differences between the two tests (p = .417).

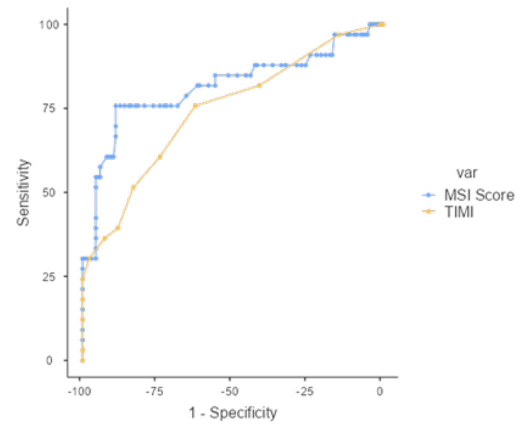

Figure 2 Combined ROC Curves for MSI and TIMI in predicting In-hospital Cardiogenic Shock

Predicting In-hospital Cardiogenic Shock. With regards to predicting occurrence of Cardiogenic Shock, for the MSI scale, similarly a comprehensive examination spans cutoff points ranging from 0.31 to 3.03. The Youden Index, spanning from 0 to 0.647, consistently aligns with an Area Under the Curve (AUC) of 0.815. The optimal cutoff point surfaces at 1.02, giving 75.76% sensitivity and 88.97% specificity. This produces a harmonized metric score of 1.65, where true positives count to 25, true negatives amount to 121, false negatives stand at 8, and false positives are 25.

In contrast, the TIMI scale undergoes inspection across a spectrum of cutoff points from 1 to 14. The Youden Index fluctuates from 0 to 0.383, with a consistent AUC of 0.743. The optimal cutoff point appears at 5, signifying 75.76% sensitivity and 62.5% specificity. This equates to a metric score of 1.38, presenting 25 true positives, 85 true negatives, 51 false positives, and 8 false negatives. As seen in Figure 2, the ROC curve visually summarizes the sensitivity-specificity trade-off for both scales. While a visual inspection suggests higher accuracy for MSI in predicting cardiogenic shock, the DeLong Test of Difference between Areas Under the Curve (AUCs) reveals non-significant AUC differences between the two tests (p = 0.24).

Predicting Occurrence of Revascularization. In terms of predicting occurrence of Revascularization, for the MSI scale, likewise the examination spans cutoff points ranging from 0.31 to 3.03. The Youden Index, spanning from 0 to 0.142, consistently aligns with an Area Under the Curve (AUC) of 0.384. The optimal cutoff point surfaces at 0.52, affording 95.42% sensitivity and 18.75% specificity. This yields a harmonized metric score of 1.14, where true positives tally to 146, true negatives to 3, false negatives at 7, and false positives are 13.

In contrast, the TIMI scale undergoes inspection across

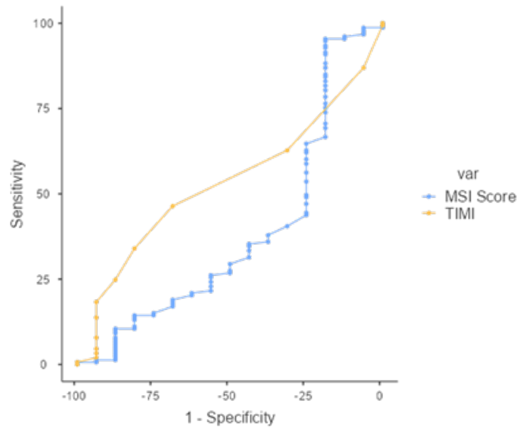

Figure 3. Combined ROC Curves for MSI and TIMI in predicting Occurrence of Revascularization

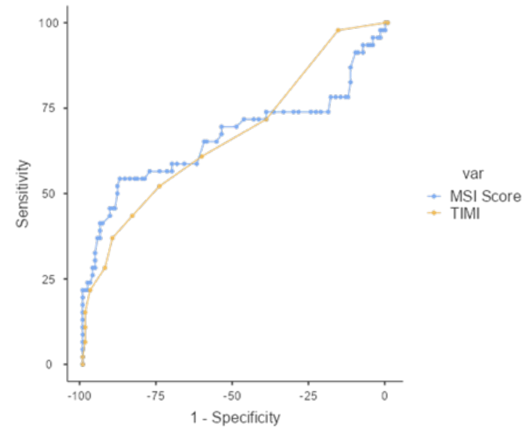

Figure 4. Combined ROC Curves for MSI and TIMI in predicting In-hospital Life-threatening Arrhythmia

cutoff points from 1 to 14. The Youden Index fluctuates from 0 to 0.152, with a consistent AUC of 0.533. The optimal cutoff point appears at 6, signifying 33.99% sensitivity and 81.25% specificity. This equates to a metric score of 1.152, presenting 52 true positives, 13 true negatives, 3 false positives, and 101 false negatives.

As seen in Figure 3, the ROC curve visually evaluates the sensitivity-specificity trade-off for both scales. Again, while a visual inspection suggests higher accuracy for MSI in predicting revascularization, the DeLong Test of Difference between Areas Under the Curve (AUCs) reveals non-significant AUC differences between the two tests (p=0.453).

Predicting Occurrence of In-hospital Life-threatening Arrhythmia. In predicting occurrence of Arrhythmia, for the MSI scale, similarly a comprehensive examination spans cutoff points ranging from 0.31 to 3.03. The Youden Index, spanning from 0 to 0.422, consistently aligns with an Area Under the Curve (AUC) of 0.665. The optimal cutoff point surfaces at 1.02, affording 54.35% sensitivity and 87.8% specificity. This yields a harmonized metric score of 1.422, where true positives tally to 25, true negatives to 108, false negatives at 21, and false positives are 15.

In comparison, the TIMI scale undergoes inspection across cutoff points from 1 to 14. The Youden Index fluctuates from 0 to 0.272, with a consistent AUC of 0.672. The optimal cutoff point appears at 7, signifying 43.48% sensitivity and 83.74% specificity. This equates to a metric score of 1.27, presenting 20 true positives, 103 true negatives, 20 false positives, and 26 false negatives. As seen in Figure 3, the ROC curve visually reviews the sensitivity-specificity trade-off for both scales. While a visual inspection suggests higher accuracy for MSI in predicting arrhythmia, the DeLong Test of Difference between Areas Under the Curve (AUCs) reveals non-significant AUC differences between the two tests (p=0.921).

Predicting Occurrence of In-hospital Arrest. In predicting occurrence of Arrest, for the MSI scale, similarly a comprehensive examination spans cutoff points ranging from 0.31 to 3.03. The Youden Index, spanning from 0 to 0.649, consistently aligns with an Area Under the Curve (AUC) of 0.861. The optimal cutoff point surfaces at 1.18, affording 72.22% sensitivity and 92.82% specificity. This yields a harmonized metric score of 1.649, where true positives tally to 13, true negatives to 140, false negatives at 5, and false positives are 11.

In comparison, the TIMI scale undergoes inspection across cutoff points from 1 to 14. The Youden Index fluctuates from 0 to 0.543, with a consistent AUC of 0.803. The optimal cutoff point appears at 7, signifying 72.22% sensitivity and 82.12% specificity. This equates to a metric score of 1.54, presenting 13 true positives, 124 true negatives, 27 false positives, and five false negatives.

As seen in *Figure 3*, the ROC curve visually reviews the sensitivity-specificity trade-off for both scales. While a visual inspection suggests higher accuracy for MSI in predicting arrhythmia, the DeLong Test of Difference between Areas Under the Curve (AUCs) reveals non-

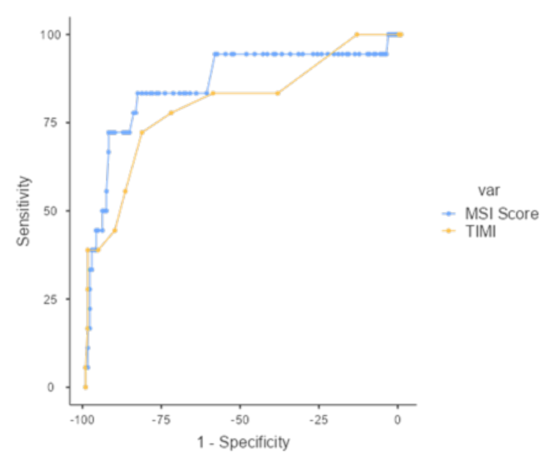

Figure 5. Combined ROC Curves for MSI and TIMI in predicting In-hospital Arrest

significant AUC differences between the two tests (*p=0.416*).

Table III summarizes the specificity and sensitivity of MSI and TIMI in predicting in-hospital outcomes. However, as stated previously, DeLong Test of Difference between Areas Under the Curve (AUCs) revealed non-significant AUC differences between the two tests.

Discussion

In patients diagnosed with ACS, risk assessment tools/prognostic models have been developed in objectively assessing risk of mortality and other MACE using clinical and readily available diagnostic parameters. The use of these models allow early prognostication, thus are valuable in deciding on management (i.e. immediate/early invasive strategy) and site of care.[17] This study was conducted to evaluate the utility of MSI, more commonly used in trauma patients, in predicting in-hospital mortality among patients admitted for ACS that could easily be done in the emergency department for early risk stratification.

This study showed that an MSI score ≥1 was significantly and independently associated with in-hospital mortality in patients with ACS (*p* < *0.001*) having 82.35%% sensitivity and 82.89%% specificity for predicting in-hospital mortality. This is consistent with findings of recent studies in other countries conducted by Pramudyo et al., Bondariyan et al., and Abreu et al., which separately concluded similar findings.[15,18,19] In addition, this study revealed that an MSI score ≥ 1 was also significantly associated with higher rates of cardiogenic shock, arrhythmia, and revascularization making MSI a reliable prognostic indicator. Moreover, the investigation of hemodynamics between the MSI ≥ 1 and MSI < 1 groups also reveal significant consistent differences, wherein patients with MSI ≥ 1 exhibit lower SBP, DBP and MAP, with higher HR.

Several studies have proposed probable reasons correlating a high MSI score, which incorporates MAP, with higher mortality rate. MAP reflects the systolic and diastolic blood pressure, which is defined by the cardiac output. A decline in MAP, which was significantly seen in all our patients with MSI ≥ 1, may reflect decline in left ventricular stroke function and cardiac index, thus may be indicative of cardiac dysfunction subsequently resulting to higher mortality rate.[15,20] In addition, a higher heart rate, also significantly observed in our MSI ≥ 1 population studied, result to a higher MSI due to sympathetic nerve hyperactivity. This is also related to the degree of left ventricular dysfunction.[21] These proposed mechanisms are correlated with the hemodynamics of our patients, particularly in the high MSI group.

Majority of patients admitted for ACS were in the older age group with overall mean age of 58.50 years, with similar findings reported in previously conducted studies in Asia.[22-23] Our results revealed that patients had a mean age of 59.03 years (±16.15) for the high MSI group, and 58.34 for the low MSI group, with slight male preponderance for high MSI score. However, *t-test* for independent groups indicates no significant age difference between the two MSI groups (*p = 0.766*), and sex distribution does not vary significantly between the two groups, as revealed by the chi-square test (*p = 0.117*). Similarly, analysis of association between MSI score and the comorbidities of patients revealed no statistically significant differences. Consistently, several studies also revealed an insignificant difference in patients' comorbidities between MSI score.[12,15,18] Differences in BMI, smoking history, and family history of ACS also revealed no statistical significance in this study.

Other commonly used assessment tools include GRACE, PURSUIT (Platelet Glycoprotein IIb/IIIa in Unstable Angina: Receptor Suppression Using Integrilin Therapy) scoring, and the TIMI risk score. According to several studies, both the TIMI and GRACE risk scoring systems have significant discriminatory ability for mortality and clinical outcomes in patients with myocardial infarction.[24] The TIMI risk scoring is considered simpler to use, and is also widely applicable in the emergency department similarly with the MSI. Thus, this study compared MSI to the TIMI risk scoring.

Our study revealed that there was a significant association between the TIMI risk score and MSI of all the admitted ACS patients. The TIMI risk score, indicative of the severity of coronary artery disease, was noted to be significantly higher in the MSI ≥ 1 group (*p* < *0.001*). Our study showed that both MSI and TIMI scores were good predictors of in-hospital mortality, with the AUC values of 0.848 and 0.787, respectively.

Although visual inspection as demonstrated by the ROC analysis suggested a higher accuracy for MSI in predicting arrhythmia, the DeLong Test of Difference between Areas Under the Curve (AUCs) revealed non-significant AUC differences between the two tests. Therefore, despite visual distinctions, the statistical assessment indicates comparable performance between MSI and TIMI in predicting mortality and MACE.

Conclusion

Modified shock index, particularly with a score ≥ 1, was a reliable parameter for predicting in-hospital mortality in patients presenting with Acute Coronary Syndrome. MSI is also significantly associated with in-hospital secondary outcomes (i.e. cardiogenic shock, arrest, life-threatening arrhythmia, and revascularization). MSI showed comparable performance with the established TIMI risk scoring. Thus, MSI was shown to be a valuable prognostic bedside tool for ACS patients admitted in Notre Dame de Chartres Hospital.

Limitations and Recommendations

This study was a retrospective single-centered study, and only a relatively small sample size was involved. Nevertheless, patient's charts were examined in detail to avoid missing data. Still, selection bias could not be avoided. Subsequent research that will be conducted should involve a larger population, or could be a multi-center study. This research only focused on short-term outcomes of ACS patients admitted, and no outpatient follow-up was done. Long-term outcomes of patients involved also need to be studied. Lastly, the Modified shock Index should also be compared to other established risk assessment tools such as the GRACE risk stratification.

References

1. Rezaianzadeh A, Moftakhar L, Seif M, Johari MG, Hosseini SV, Dehghani SS. Incidence and risk factors of cardiovascular disease among population aged 40–70 years: a population-based cohort study in the South of Iran. Tropical Medicine and Health [Internet]. 2023 Jun 12;51(1). Available from: https://doi.org/10.1186/s41182-023-00527-7
2. Fanta K, Daba FB, Asefa ET, Melaku T, Chelkeba L, Fekadu G, et al. Management and 30-Day mortality of Acute Coronary Syndrome in a Resource-Limited Setting: Insight from Ethiopia. A Prospective Cohort study. Frontiers in Cardiovascular Medicine [Internet]. 2021 Sep 17;8. Available from: https://doi.org/10.3389/fcvm.2021.707700
3. Heart disease remains top cause of death in PH in 2021: PSA [Internet]. Philippine News Agency. Available from: https://www.pna.gov.ph/articles/1168439
4. Collet JP, Thiele H, Barbato E, Barthélémy O, Bauersachs J, Bhatt DL, et al. 2020 ESC Guidelines for the management of acute coronary syndromes in patients presenting without
5. Lawton JS, Lawton JS, Tamis-Holland JE, Bates ER, Bates ER, Bischoff JM, et al. 2021 ACC/AHA/SCAI Guideline for Coronary Artery Revascularization. Journal of the American College of Cardiology [Internet]. 2022 Jan 1;79(2):e21–129. Available from: https://doi.org/10.1016/j.jacc.2021.09.006
6. Lazaro VL. 2014 PHA Clinical Practice Guidelines for the Diagnosis and Management of Patients with Coronary Heart Disease. ASEAN Heart Journal [Internet]. 2016 Jan 1;24(1). Available from: https://doi.org/10.7603/s40602-016-0003-6
7. Liu YC, Liu J, Fang Z, Shan G, Xu J, Qi Z, et al. Modified shock index and mortality rate of emergency patients. World Journal of Emergency Medicine [Internet]. 2012 Jan 1;3(2):114. Available from: https://doi.org/10.5847/wjem.j.issn.1920-8642.2012.02.006
8. Çakır E, Bindal A, Yılmaz PÖ, Doğu C, Mutlu NM, Turan İÖ. The relationship of shock index, modified shock index, and age shock index with mortality in the intensive care unit Care Unit. Annals of Medical Research [Internet]. 2019 Jan 1;26(10):2148. Available from: https://doi.org/10.5455/annalsmedres.2019.07.371
9. Pramudyo M, Marindani V, Achmad C, Putra ICS. Modified shock Index as simple clinical Independent Predictor of In-Hospital mortality in Acute Coronary Syndrome patients: A Retrospective cohort study. Frontiers in Cardiovascular Medicine [Internet]. 2022 Jun 9;9. Available from: https://doi.org/10.3389/fcvm.2022.915881
10. Burstein B, Tabi M, Barsness GW, Bell MR, Kashani K, Jentzer JC. Association between mean arterial pressure during the first 24 hours and hospital mortality in patients with cardiogenic shock. Critical Care [Internet]. 2020 Aug 20;24(1). Available from: https://doi.org/10.1186/s13054-020-03217-6
11. Takata Y, Tian C, Song J, He D, Sun Z. Derivation and Validation of Shock Index as a parameter for Predicting Long-term Prognosis in Patients with Acute Coronary Syndrome. Scientific Reports [Internet]. 2017 Sep 20;7(1). Available from: https://doi.org/10.1038/s41598-017-12180-2
12. Shangguan Q, Xu J, Su H, Li J, Wang W, Hong K, et al. Modified Shock Index is a Predictor for 7-Day Outcomes in Patients With STEMI. the American Journal of Emergency Medicine [Internet]. 2015 Aug 1;33(8):1072–5. Available from: https://doi.org/10.1016/j.ajem.2015.04.066
13. Chiang CC, Lin CF, Liu PH, Chen FC, Chiu IM, Cheng FJ. Clinical validation of the Shock Index, Modified Shock Index, Delta Shock Index, and Shock Index-C for Emergency Department ST-Segment Elevation myocardial infarction. Journal of Clinical Medicine [Internet]. 2022 Oct 1;11(19):5839. Available from: https://doi.org/10.3390/jcm11195839
14. Schmitz T, Harmel E, Linseisen J, Kirchberger I, Heier M, Peters A, et al. Shock index and modified shock index are predictors of long-term mortality not only in STEMI but also in NSTEMI patients. Annals of Medicine (Helsinki)/Annals of Medicine [Internet]. 2022 Apr 4;54(1):900–8. Available from: https://doi.org/10.1080/07853890.2022.2056240
15. Pramudyo M, Putra ICS, Kamarullah W, Prameswari HS, Saboe A, Akbar MR. Elevated shock index and modified shock index are associated with mortality and major adverse cardiac events in patients with acute myocardial infarction: A systematic review and meta-analysis. F1000Research [Internet]. 2022 Aug 11; 11:926. Available from: https://doi.org/10.12688/f1000research.124251.1
16. DeMers D, Wachs D. Physiology, mean arterial pressure [Internet]. StatPearls - NCBI Bookshelf. 2023. Available from: https://www.ncbi.nlm.nih.gov/books/NBK538226/
17. Byrne RA, Rosselló X, Coughlan JJ, Barbato E, Berry C, Chieffo A, et al. 2023 ESC Guidelines for the management of acute coronary syndromes. European Heart Journal [Internet]. 2023 Aug 25;44(38):3720–826. Available from: https://doi.org/10.1093/eurheartj/ehad191
18. Abreu G, Azevedo P, Braga CG, Vieira C, Pereira M, Martins J, et al. Modified shock index: A bedside clinical index for risk assessment of ST-segment elevation myocardial infarction at presentation. Revista Portuguesa De Cardiologia [Internet]. 2018 Jun 1;37(6):481–8. Available from: https://doi.org/10.1016/j.repc.2017.07.018
19. Bondariyan N, Vakhshoori M, Sadeghpour N, Shafie D. Prognostic Value of Shock Index, Modified Shock Index, and Age-Adjusted Derivatives in Prediction of In-Hospital Mortality in Patients with Acute Decompensated Heart Failure: Persian Registry of Cardiovascular Disease/ Heart Failure Study. The Anatolian Journal of Cardiology [Internet]. 2022 Mar 23;26(3):210–7. Available from: https://doi.org/10.5152/anatoljcardiol.2021.671
20. Wang G, Wang R, Liu L, Wang J, Zhou L. Comparison of shock index-based risk indices for predicting in-hospital outcomes in patients with ST-segment elevation myocardial infarction undergoing percutaneous coronary intervention. Journal of International Medical Research [Internet]. 2021 Mar 1;49(3):030006052110005. Available from: https://doi.org/10.1177/03000605211000506
21. Graham LN, Smith PA, Stoker JB, Mackintosh A, Mary DASG. Sympathetic neural hyperactivity and its normalization following unstable angina and acute myocardial infarction. Clinical Science [Internet]. 2004 Jun 1;106(6):605–11. Available from: https://doi.org/10.1042/cs20030376
22. Ohsawa M, Tanno K, Itoh T. Age-Specific incidence rates of acute coronary syndrome in Japan ― a special gift from a collaboration of cardiologists and epidemiologists ―. Circulation Journal [Internet]. 2021 Sep 24;85(10):1731–4. Available from: https://doi.org/10.1253/circj.cj-21-0502
23. Khaznadar AA, Salh RW. Impact of age on risk factors and clinical manifestations of acute coronary syndrome: Observations from the Coronary Care Unit of Sulaimani, Iraq. Hospital Practices and Research [Internet]. 2020 Mar 18;5(1):28–34. Available from: https://doi.org/10.34172/hpr.2020.06
24. Chen Y, Huang SL, Lin S. TIMI and GRACE Risk Scores Predict Both Short-Term and Long-Term Outcomes in Chinese Patients with Acute Myocardial Infarction. PubMed [Internet]. 2018 Jan 1;34(1):4–12. Available from: https://pubmed.ncbi.nlm.nih.gov/29375219