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Evaluation of the success of shock index and its derivatives in determining mortality in STEMI cases applied to emergency department

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ABSTRACT

Objectives: Shock index (SI) and its derivatives play a crucial role in rapid prognosis and risk assessment, particularly in emergent scenarios like ST-segment elevation myocardial infarction (STEMI).

Methods: This study was conducted as single-centered and retrospective. A total of 467 cases who met the study criteria with a confirmed STEMI diagnosis were included. SI, modified SI (MSI), age SI (ASI), and age-modified SI (AMSI) scores of the cases were calculated and compared. In this study, $p < 0.05$ was accepted as the statistical significance level.

Results: Calculated scores were compared among cases meeting STEMI criteria. Mortal cases displayed significantly higher SI, MSI, ASI, and AMSI, as well as elevated heart rates and lowered SBP, DBP, and MAP values. ASI exhibited the highest predictive success for mortality (AUC: 0.802), followed by AMSI (AUC: 0.798). AMSI demonstrated superior significance in estimating major adverse cardiovascular events (MACE) ($p < 0.001$ for each parameter).

Conclusions: ASI proved most effective in gauging mortality risk, while AMSI excelled in predicting MACE risk among SI derivatives. These indices hold promise for guiding patient triage and emergency care in STEMI cases, owing to their simplicity and predictive capacity.

Keywords: Emergency department, mortality, shock index, modified shock index, STEMI

Shock index (SI) was defined as heart rate divided by systolic blood pressure to assess the hemodynamic stabilization of patients and was first described in 1967 [1]. Over time, to evaluate hemodynamic instability, shock index derivatives have been developed by modifying the shock index. Among these modifications, modified SI (MSI), which uses mean arterial pressure instead of systolic blood pressure, and age SI (ASI) are some of the modified indices in the literature [2].

It has been investigated whether it is a useful tool for early risk assessment of underlying diseases in patients, especially in the emergency department [3]. Those critical diseases include traumatic injuries, sepsis, pulmonary embolism, cardiovascular diseases, and ectopic pregnancy [4-7].

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Studies are showing that SI is a successful measure in estimating medium and long-term mortality in ST-segment elevation myocardial infarction (STEMI), which is one of the common cardiovascular emergencies with a high risk of mortality and morbidity, that requires urgent intervention [5, 8, 9]. However, there are few or no studies in the literature investigating whether MSI, ASI, and other SI indices are more successful in determining the risk of mortality in STEMI cases.

In our study, we aimed to investigate the success of SI, MSI, ASI, and age-modified SI (AMSI) in assessing mortality in patients who presented to the emergency department with STEMI.

METHODS

This study was conducted retrospectively between January 1, 2019, and January 1, 2021. A total of 467 STEMI patients admitted to the emergency department of our university hospital were included in the study.

Study Population

This study was carried out in a single center, in the emergency department of a tertiary education and research hospital, retrospectively. Our hospital is the central hospital of the region in terms of PCI and PCI is performed 7 days 24 hours. Patients aged 18 years and older with STEMI who applied to the emergency department between January 1, 2019, and January 1, 2021 were included in the study. Among those, pregnant patients (1), patients not diagnosed with ACS after PCI (23), patients diagnosed with ACS other than STEMI (18), patients presenting tachyarrhythmia (31), patients with primary kidney or blood disease (11), patients with advanced liver (4), kidney (7) or heart failure (13) were excluded from the study. (Fig. 1. Flow Chart). Patients with unknown or undefined medical histories were also excluded from the study. Patients with unstable vital signs at the time of admission were not included in the study either.

Data collection

Electrocardiography (ECG) measurements were taken at the time of application from patients who were diagnosed with STEMI and accepted to participate in the study. Patients with chest pain lasting longer than 30 minutes or equivalent symptoms, patients with ST-segment elevation in at least two adjacent ECG leads (at least 0.2 mV in V2 and V3 in men or at least 0.15 mV in women; at least 0.1 mV) in all leads except V2 and V3) or patients with new-onset left bundle branch block were diagnosed with STEMI regarding current guidelines [10, 11]. The STEMI status of each patient included in the study was evaluated by a cardiologist.

Percutaneous coronary intervention (PCI), the golden standard treatment, was performed in all patients with STEMI. The number of vascular lesions of the patients (lesions of two vessels and above were defined as multi-vessel) was recorded by the cardiologist after the procedure.

Demographic data (age, gender, cardiovascular risk factors, chronic disease history), measured vital signs (systolic blood pressure (SBP), diastolic blood pressure (DBP), mean arterial pressure (MAP), and pulse rate) and ECG findings of all patients included in the study were recorded. In addition to these, fatal arrhythmia status requiring intervention (ventricular tachycardia (VT) and ventricular fibrillation (VF)), heart failure development according to Killip criteria, mortality. and cardiogenic shock states were named as major adverse cardiovascular event (MACE) and were recorded.

Data Definition and Calculation

Mean blood pressure (MAP) was calculated as [(2x DBP) + SBP]/3.

SI, MSI, ASI, and AMSI were calculated using the following formulas:

SI = Heart rate/ SBP; MSI = Heart rate/ MAP; ASI = SI × age and AMSI = MSI × age.

Statistical Analysis

Statistical analysis was performed using SPSS 23.0 for Windows® statistical program (IBM Inc. Chicago, IL, USA). Number, percentage, mean, standard deviation were used in the presentation of descriptive data. The conformity of the data to the normal distribution was evaluated with the Kolmogorov-Smirnov Test. Pearson chi-square test and Fisher's Exact test were used to compare categorical data. T Test was used to compare two independent nu-

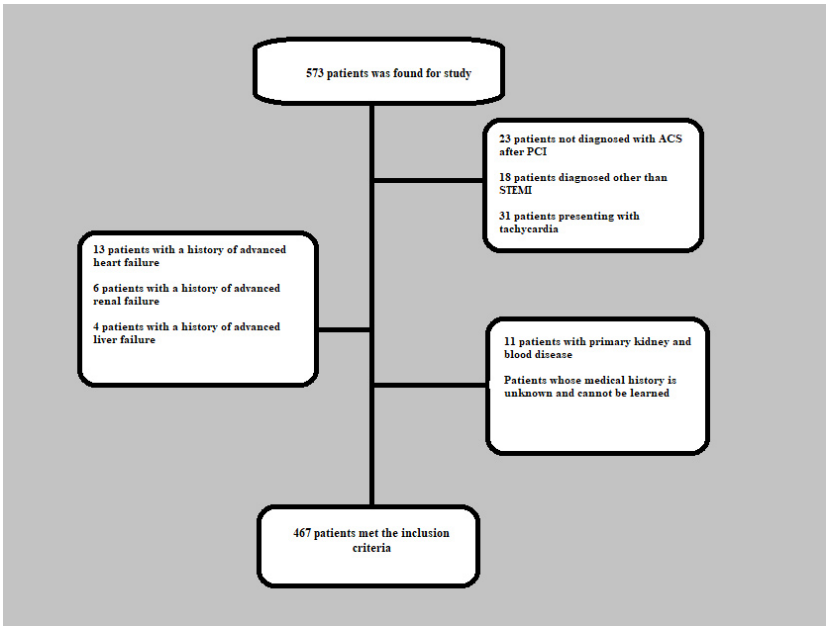

Fig. 1. Flow Chart

meric data, Kruskal Wallis Test and ANOVA test were used to compare triple numeric data. ROC curve analysis was performed to determine the cut-off values, AUC, sensitivity, and specificity of SI and its derivatives. Results were considered significant at $p < 0.05$, with a 95% confidence interval.

RESULTS

Our study was implemented with 467 patients who met the inclusion criteria. 26.3% (n = 123) of the cases were female, 73.7% (n = 344) were male, and the mean age was 61.11 ± 12.33 years in all cases. The mean age was 59.31 ± 11.90 years in men and 66.17 ± 12.17 years in women, which was significantly higher in women ($p < 0.001$).

Demographic and clinical data of the cases were evaluated according to their mortality status. The mean age was significantly higher in cases with mortality ($p < 0.001$). In cases with mortality, SBP, DBP, and MAP were significantly lower ($p < 0.001$ for all) whereas heart rate was significantly higher than the surviving cases ($p < 0.001$). Again, while the history of DM and CAD was significantly higher in cases with mortality, ($p = 0.044$, $p = 0.016$ respectively); HT and smoking were significantly lower ($p = 0.003$, $p = 0.006$; respectively). In cases with mortality, SI, MSI, ASI, and AMSI were significantly higher compared to surviving cases ($p < 0.001$ for all). It was observed that the inferior STEMI type was significantly higher in patients with mortality compared to those who survived. There was no mortality due to posterior and inferolateral STEMI. In cases with mortality, single-vessel occlusion was significantly higher; in addition, RCA occlusion in a single vessel was found to be significantly higher as well. ($p = 0.003$) (Table 1).

ROC analysis was performed to evaluate the success of the SI, MSI, ASI, and AMSI in predicting mortality of the cases (Fig. 2). According to the analysis, the most successful index in predicting mortality was ASI (AUC: 0.802 [95% CI: 0.749-0.855]), followed by AMSI (AUC: 0.798 [95% CI: 0.744-0.851]). AUC and cut-off values of other indices are given in Table 2.

Demographic and clinical data of the cases were analyzed according to the cut-off values obtained from the ROC analysis. It was calculated as 0.603 for SI (SI < 0.603; SI ≥ 0.603); 0.839 for MSI (MSI < 0.839; MSI ≥ 0.839); 34.88 for ASI (ASI < 34.88; ASI ≥ 34.88) and 60.18 for AMSI (AMSI < 60.18; AMSI ≥ 60.18) and the data were compared again according to the cut-off value. AMSI was found to be the most successful index to predict MACE ($p < 0.001$ for each parameter of MACE). The relations of the other demographic and clinical data of the cases according to the cut-off values of the indexes are given in Table 3.

Table 1. Evaluation of the demographic and clinical data of the cases according to their outcomes

Parameters	All cases (n = 467)	Exitus (n = 76)	Surviviors (n = 391)	*p value*
Age (years)	61.11 ± 12.33	66.51 ± 12.65	59.90 ± 12.48	**< 0.001**
Gender, n (%)				
Female	123 (26.3)	21 (17.1)	102 (82.9)	0.780
Male	344 (73.7)	55 (16.0)	289 (84.0)	
Hemodynamics				
SBP (mmHg)	131.67 ± 30.54	111.87 ± 28.05	135.76 ± 29.69	**< 0.001**
DBP (mmHg)	73.14 ± 15.86	63.49 ± 20.18	76.22 ± 16.55	**< 0.001**
MAP (mmHg)	95.92 ± 24.88	79.61 ± 21.88	96.03 ± 19.52	**< 0.001**
Pulse (rate/minutes)	73.98 ± 17.73	89.70 ± 26.20	80.56 ± 18.56	**< 0.001**
Cardiovascular risk factors, n (%)				
Hypertension	217 (46.5)	33 (43.5)	241 (61.8)	**0.003**
Diabetes Mellitus	128 (27.4)	28 (36.8)	100 (25.6)	**0.044**
Dyslipidemia	60 (12.8)	5 (6.6)	55 (14.1)	0.074
Coronary artery disease	159 (34.0)	35 (46.1)	124 (31.7)	**0.016**
Smoking	183 (39.2)	19 (25.0)	164 (41.9)	**0.006**
Indexes				
SI	0.64 ± 0.19	0.83 ± 0.28	0.61 ± 0.15	**< 0.001**
MSI	0.91 ± 0.28	1.18 ± 0.41	0.86 ± 0.22	**< 0.001**
ASI	39.81 ± 16.24	55.06 ± 21.77	36.70 ± 13.16	**< 0.001**
AMSI	56.36 ± 23.40	77.93 ± 30.64	51.88 ± 19.22	**< 0.001**
STEMI type, n (%)				
Anterior	159 (34.0)	26 (34.0)	141 (36.1)	**0.003**
Inferior	240 (51.4)	42 (65.8)	190 (48.6)	
Lateral	30 (6.4)	8 (10.5)	22 (5.6)	
Posterior	25 (5.4)	0 (0.0)	25 (6.4)	
Inferiolateral	13 (2.8)	0 (0.0)	13 (3.3)	
Vessel occlusion type, n (%)				
Single vessel occlusion	298 (63.8)	56 (73.7)	242 (61.9)	**0.003**
LAD	104 (22.3)	13 (17.1)	91 (23.3)	
RCA	159 (34.0)	40 (52.6)	119 (30.4)	
Cx	35 (7.5)	3 (3.9)	32 (8.2)	
Multiple vessel occlusion	169 (36.2)	20 (26.3)	149 (38.1)	

Data are shown mean ± standard deviation or n (%). SBP = systolic blood pressure, DBP = diastolic blood pressure, MAP = mean arterial pressure, SI= shock Index, MSI = modified shock index, ASI = age-shock index, AMSI = age-modified SI, LAD = left anterior descending, RCA = right coronary artery, Cx = circumplex

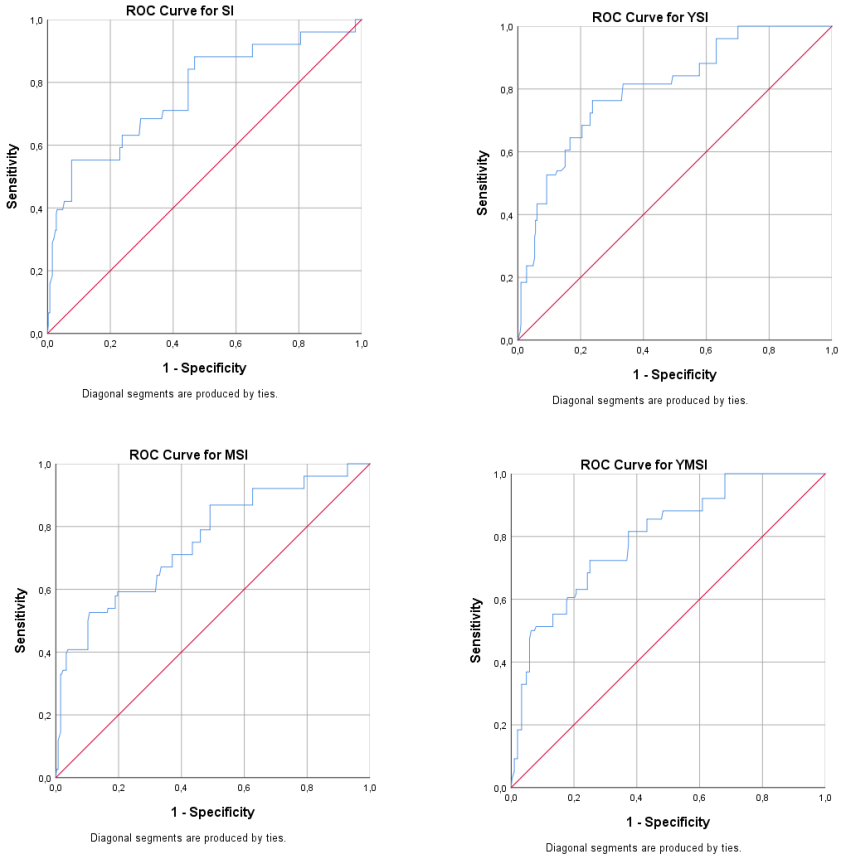

Fig. 2. STEMI ROC analysis results in evaluating the success of SI, MSI, ASI and AMSI in determining mortality.

DISCUSSION

According to the results of our study, for patients with STEMI diagnosis who underwent PCI in the emergency department, AMSI is found to be more accurate than SI, MSI, and ASI in estimating the risk of 30-day in-hospital MACE, whereas ASI was found to be more successful than SI, MSI, and AMSI in determining in-hospital mortality.

The SI was originally introduced to assess hemodynamic stability and then continued to be used as an early shock risk index in cases of trauma, bleeding, sepsis, and cardiogenic shock (pulmonary embolism, etc.) [12]. The use of SI in patients with acute coronary syndrome is not new either. Bilkova *et al*. [13], in 2011, measured the success of SI in the evaluation of in-hospital mortality, and short and long-term MACE in STEMI cases and reported that high SI was a suc-

Table 2. Evaluation of ROC analysis results in evaluating the success of SI, MSI, ASI and AMSI in determining mortality in cases

Parameters	Cut-off Value	Area Under the Curve (AUC)	Sensivity %	Specificity %	*p value*	%95 CI	
						Lower Bound	Upper Bound
SI	0.603	0.766	88	53	**< 0.001**	0.702	0.830
MSI	0.839	0.754	86	51	**< 0.001**	0.691	0.818
ASI	34.88	0.802	84	50	**< 0.001**	0.749	0.855
AMSI	60.18	0.798	72	75	**< 0.001**	0.74	0.851

SI = shock Index, MSI = modified shock index, ASI = age-shock index, AMSI = age-modified SI

Table 3. Comparison of demographic and clinical data of indices according to ROC analysis cut-off values

Parameters	SI			MSI			ASI			AMSI		
	< 0.6 (n = 211)	≥ 0.6 (n = 256)	*p value*	< 0.83 (n = 191)	≥ 0.83 (n = 276)	*p value*	< 34.88 (n = 207)	≥ 34.88 (n = 260)	*p value*	< 60.18 (n = 314)	≥ 60.18 (n = 153)	*p value*
Age (years)	59.82 ± 11.79	62.18 ± 12.69	**0.040**	60.98 ± 12.32	61.21 ± 12.36	0.845	54.32 ± 10.37	66.52 ± 11.05	**< 0.001**	56.34 ± 9.71	70.90 ± 1.35	**< 0.001**
Gender, n (%)												
Female	39 (18.5)	84 (32.8)	**< 0.001**	40 (20.9)	83 (30.1)	**0.028**	33 (15.9)	90 (34.6)	**< 0.001**	73 (23.2)	50 (32.7)	**0.030**
Male	172 (81.5)	172 (67.2)		151 (79.1)	193 (69.9)		174 (84.1)	170 (65.4)		241 (76.8)	103 (67.3)	
MACE (-), n (%)	179 (84.8)	185 (72.3)	**0.001**	164 (85.9)	200 (72.5)	**0.001**	182 (87.9)	182 (70.0)	**< 0.001**	271 (86.3)	93 (60.8)	**< 0.001**
MACE (+), n (%)	32 (15.2)	71 (27.7)		27 (14.1)	76 (27.5)		25 (12.1)	78 (30.0)		43 (13.7)	60 (39.2)	
MACE, n (%)												
VF/VT in ED	12 (5.7)	46 (18.0)	**< 0.001**	11 (5.8)	47 (17.0)	**< 0.001**	11 (5.3)	47 (18.1)	**< 0.001**	17 (5.4)	41 (26.8)	**< 0.001**
CHF-Killip	12 (5.7)	34 (13.3)	**0.006**	14 (7.3)	32 (11.6)	0.128	8 (3.9)	38 (14.6)	**< 0.001**	14 (4.5)	32 (20.9)	**< 0.001**
Cardiogenic shock	22 (10.4)	44 (17.2)	**0.037**	17 (8.9)	49 (17.8)	**0.007**	18 (8.7)	48 (18.5)	**0.003**	21 (6.7)	45 (29.4)	**< 0.001**
Arrest in ED	15 (7.1)	41 (16.0)	**0.003**	14 (7.3)	42 (15.2)	**0.010**	14 (6.8)	42 (16.2)	**0.002**	14 (4.5)	42 (27.5)	**< 0.001**
Mortality, n (%)												
Absent	202 (95.7)	189 (73.8)	**< 0.001**	181(94.8)	210 (76.1)	**< 0.001**	195 (94.2)	196 (75.4)	**< 0.001**	293 (93.3)	98 (64.1)	**<0.001**
Present	9 (4.3)	67 (26.2)		10 (5.2)	66 (23.9)		12 (5.8)	64 (24.6)		21 (6.7)	55 (35.9)	
Cardiovascular risk factors, n (%)												
Hypertension	91 (43.1)	140 (54.8)	0.189	79 (41.4)	138 (50.0)	0.066	56 (27.1)	160 (61.9)	**< 0.001**	114 (36.3)	103 (67.3)	**< 0.001**
Diabetes mellitus	61 (28.9)	67 (26.2)	0.509	62 (32.5)	66 (23.9)	**0.042**	43 (20.8)	85 (32.7)	**0.004**	78 (24.8)	50 (32.7)	0.075
Dyslipidemia	35 (16.6)	25 (9.8)	**0.028**	26 (13.6)	34 (12.3)	0.681	22 (10.6)	38 (14.6)	0.201	42 (13.4)	18 (11.8)	0.625
Coronary artery disease	73 (34.6)	86 (33.6)	0.820	57 (29.8)	102 (37.0)	0.111	51 (24.6)	108 (41.5)	**< 0.001**	102 (32.5)	57 (37.3)	0.307
Smoking	100 (47.4)	83 (32.4)	**0.001**	79 (41.4)	104 (37.7)	0.423	101 (48.8)	82 (31.5)	**< 0.001**	156 (49.7)	27 (17.69)	**< 0.001**
STEMI type, n (%)												
Anterior	72 (34.6)	86 (33.6)	0.651	54 (28.3)	105 (38.0)	**0.004**	66 (31.9)	93 (35.8)	0.106	99 (31.5)	60 (39.2)	0.396
Inferior	108 (51.2)	132 (51.6)		118 (61.8)	122 (44.2)		110 (53.1)	130 (50.0)		166 (52.9)	74 (48.4)	
Lateral	15 (7.1)	15 (5.9)		7 (3.7)	23 (8.3)		19 (9.2)	11 (4.2)		23 (7.3)	7 (4.6)	
Posterior	8 (3.8)	17 (6.6)		8 (4.2)	17 (6.2)		8 (3.9)	17 (6.5)		16 (5.1)	9 (5.9)	
Inferiolateral	7 (3.3)	6 (2.3)		4 (2.1)	9 (3.3)		4 (1.9)	9 (3.5)		10 (3.2)	3 (2.0)	
Vessel occlusion type, n (%)												
Single vessel occlusion	145 (68.7)	153 (59.8)	**0.020**	118 (61.8)	180 (65.2)	0.443	115 (55.7)	115 (44.3)	0.071	195 (62.1)	103 (67.3)	0.081
LAD	58 (27.5)	46 (18.0)		36 (18.8)	68 (24.6)		35 (16.9)	69 (26.5)		59 (18.8)	45 (29.4)	
RCA	67 (31.8)	92 (35.9)		69 (36.1)	90 (32.6)		71 (34.3)	88 (33.8)		111 (35.4)	48 (31.4)	
Cx	20 (9.5)	15 (5.9)		13 (6.8)	22 (8.0)		17 (8.2)	18 (6.9)		25 (8.0)	10 (6.5)	
Multiple vessel occlusion	66 (31.3)	103 (40.2)		73 (38.2)	96 (34.8)		92 (44.3)	145 (55.7)		119 (37.9)	50 (32.7)	

MACE= major adverse cardiovascular events, SBP = systolic blood pressure, DBP = diastolic blood pressure, MAB= mean arterial pressure, SI= shock Index, MSI=modified shock index, ASI= age-shock index, AMSI= age-modified SI, LAD=left anterior descending, RCA=right coronary artery, Cx= circumplex

cessful measure for anticipation of the possible consequences. Later, Reinstadler *et al*. [5], Hemradj *et al*. [14], and Zhou *et al*. [15] reported in their studies that high SI in STEMI cases was significantly associated with determining short- and long-term MACE. Again, Abe *et al*. [8], Kobayashi *et al*. [16] and Yu *et al*. [6] stated that high SI showed significant results in detecting the risk for in-hospital mortality, and short and long-term MACE development in patients with acute coronary syndrome.

In the literature, in addition to SI, modified types of this index have also been used to predict mortality. Abreu *et al*. [9] used MSI in their STEMI study and reported that high MSI was an independent predictor for six-month mortality and fatal arrhythmia. Schmitz *et al*. [17] compared the predictive values of SI and MSI regarding long-term MACE development in both STEMI and non-STEMI cases and reported that MSI was found to be more valuable than SI. Chiang *et al*. [18] found that MSI revealed a better predictive value than SI for mortality acute myocardial infarction (AMI) cases. Shangguan *et al*. [19] reported that MSI was more accurate than SI in predicting all-cause 7-day mortality in 160 cases of STEMI who underwent emergency PCI. When the results of our study were compared with the results of the studies by Schmitz *et al*. [17], Chiang *et al*. [18], and Shangguan *et al*. [19], we observed that high SI had better predictive power than MSI on the mortality of STEMI cases. One possible explanation for this might be since the mean age and admission times of the patients included in the study were not standardized, SBP and MAP measurements differentiated.

Age is one of the independent risk factors in patients with acute coronary syndrome [20, 21]. Therefore, age is integrated into many risk scoring systems, and the effect of age is frequently investigated. For this reason, we expected that ASI and AMSI, which were obtained by integrating age into SI and MSI, would provide better results in predicting mortality and MACE development in STEMI cases. In our results, we found that while ASI was more accurate in predicting mortality; AMSI provided better risk estimation in determining MACE. Yu *et al*. [6] reported that ASI was superior to SI and MSI in estimating all-cause mortality in patients that underwent PCI. In the study of Zhou *et al*. [15]; AMSI was stated to be an independent predictor of MACE development in STEMI cases. Correlatively, we observed that ASI and AMSI, which were designed by the addition of age to SI and MSI, are more significant than SI and MSI in estimating mortality and MACE.

Limitations

Our study has several limitations. One of these limitations is that our study is retrospective. However, both the hospital automation system and patient files were examined in detail to avoid missing data on the patients included in the study, and patient data were tried to be collected completely. Another limitation is that the medical history of the patients was obtained according to the statements of the patients and their relatives. Although we think that there may be errors arising from those statements in this regard, we do not think that this situation will affect our study results.

CONCLUSION

In determining the risk of mortality and MACE development in STEMI cases, ASI demonstrated better predictive power on mortality; whereas AMSI was found to be the most successful index in determining the risk of MACE. It could be concluded that these indexes can be used both in determining the appropriate health center for the patient and in emergency departments due to their easy applicability and their ability to predict mortality and MACE in STEMI cases.

Authors' Contribution

Study Conception: GY, ESB, AÇ; Study Design: GY, ESB, AÇ; Supervision: GY, ESB, AÇ; Funding: N/A; Materials: N/A; Data Collection and/or Processing: GY, ESB, AÇ; Statistical Analysis and/or Data Interpretation: GY, ESB, AÇ; Literature Review: GY, AÇ; Manuscript Preparation: GY, AÇ and Critical Review: ESB.

Conflict of interest

The author disclosed no conflict of interest during the preparation or publication of this manuscript.

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Ethical Considerations

Ethics committee approval was obtained from the university hospital ethics committee (Ethics committee dated 21.04.2022 and decision number GOEK-198). Due to the retrospective nature of the study, voluntary consent from patients or their legal heirs to participate in the study was waived. The entire study was performed in accordance with the Declaration of Helsinki.

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