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Original Article

The relationship of shock index, modified shock index, and age shock index with mortality in the intensive care unit

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Abstract

Aim: Shock indexes are associated with clinical outcomes of patients, particularly in the emergency department. The present study aimed to evaluate the predictive capacity of Shock Index, Modified Shock Index, and Age Shock Index in terms of mortality in patients admitted to intensive care units.

Material and Methods: All patients (aged >18 years) admitted to intensive care unit between January 01, 2018 and October 31, 2018 were included. Vital signs at the time of hospitalization were used to calculate Shock Index, Modified Shock Index, and Age Shock Index. Patients with shock were divided into three groups: Group 1 (septic shock), Group 2 (hypovolemic shock), and Group 3 (cardiogenic shock). The primary outcome was to evaluate intensive care unit mortality.

Results: Mortality was 37% among 308 patients included in the study. Shock Index, Modified Shock Index, and Age Shock Index levels were significantly higher in patients with mortality ($p < 0.05$). Shock Index, Modified Shock Index, and Age Shock Index levels were significantly higher than normal range in Group 1, 2, and 3 ($p < 0.05$), and the results were similar between the groups ($p > 0.05$).

Conclusion: All three shock indices were observed to be high in all patients with shock, and three shock indices were similarly significant in predicting mortality in patients admitted to intensive care units.

Keywords: Intensive care unit; shock index; modified shock index; age shock index; mortality.

INTRODUCTION

Shock Index (SI), first published by Allgower and Burri in 1967, is calculated as the ratio of heart rate (HR) to systolic blood pressure (SBP). It has been suggested to be clinically appropriate for the assessment of hemodynamic deficiency status. Normal SI values are reportedly in the range of 0.5–0.7, and increased SI has been reported to be an early sign of shock (1). An increase in SI value indicates decreased left ventricular pulse volume and acute circulatory failure. In addition, persistent elevation in SI has been associated with increased mortality. This index could be useful in predicting the severity of hypovolemic shock (2).

It has been reported that HR or SBP alone is unreliable for determining the presence of hemodynamic instability (2,3). Therefore, certain studies related to SI have reported the usefulness of this index in the risk classification of serious injury, acute critical diseases, mortality, acute myocardial infarction, and pulmonary embolism as well as in the early diagnosis of sepsis; further, it is associated with the hospitalization period of trauma patients and unscheduled hospitalization to the intensive care unit (ICU) (2-4). In a study evaluating SI demonstrated that SI ≥ 0.9 predicted mortality in critically ill patients (4).

Modified SI (MSI) is calculated by dividing HR by mean arterial pressure (MAP). Liu et al., who first reported this, have stated that diastolic blood pressure (DBP) drops earlier than SBP, and hence, MAP may be a more accurate marker for assessing disease severity. In addition, increased or decreased MSI may reflect circulatory hypo-

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and hyperdynamic states, and have been associated with increased mortality in the emergency department (5). Few studies on age SI (ASI) have reported that ASI is superior to SI and MSI in predicting mortality (6,7).

The relationship between SI, MSI, ASI, and mortality has been evaluated in infection, trauma, postpartum hemorrhage, and cardiovascular diseases (particularly among patients in the emergency department) (3,6-11). To the best of our knowledge, there are few studies evaluating the relationship between SI and MSI values and morbidity and mortality of patients in ICU; moreover, there are no studies evaluating ASI in this aspect (4,12). The present study aimed to investigate relationship among SI, MSI, ASI values and mortality as primary outcome of the patients admitted to the ICU.

MATERIAL and METHODS

Study Design and Patient Selection

The present study was performed by retrospective cohort evaluation of patient records of the Health Sciences University, Anesthesiology and Critical Care Clinic. All patients (aged >18 years) admitted to ICU between January 1,2018 and October 31,2018 (10 months period) were included in our study. Our hospital was a third level referral hospital with bed number of 25 in ICU, where approximately 700 patients were treated each year.

Local ethics committee approval was obtained (ethics number: E-15-709) and the study was conducted with full compliance to the Helsinki Declaration and the ethical standards of the responsible committee on human experimentation (institutional and national). Age of patients at the time of admission, underlying diseases [yes (diabetes mellitus, hypertension, malignancy, etc.) or no], patients at risk for shock [Group 1 (septic shock): infections (pneumonia, sepsis, and meningitis); Group 2 (hypovolemic shock): hemorrhage (postoperative, trauma, gunshot wound, and coagulopathy); and Group 3 (cardiogenic shock): cardiac causes (cardiogenic and myocardial ischemia)], hospitalization duration, mortality, SBP, DBP, MAP, HR, SI, MSI, and ASI data were obtained from the patient records. Patients who were admitted to ICU owing to other reasons (cerebrovascular stroke, metabolic causes, intoxications, end stage malignancies, etc.) were excluded. The same protocol was applied to all patients in the treatment of shock.

MAP, SI, MSI, and ASI Calculation
Blood pressure was measured using noninvasive blood pressure cuff.
MAP=[SBP (mm Hg × 2) + DBP (mm Hg)] / 3.
SI=HR (heart beat/ minute) / SBP (mm Hg).
MSI=HR (heart beat/ minute) / MAP (5).
ASI=Age x SI (7).

Overall mortality, underlying diseases and the reasons for hospitalization were compared with age, SBP, DBP, MAP, HR, SI, MSI, and ASI. Further, age, hospitalization duration, and SBP, DBP, MAP, HR, SI, MSI, and ASI were compared among three shock groups.

Data Analysis

Recorded data was transferred to a digital environment. The data were statistically analyzed using Statistical Package for Social Sciences (SPSS) version 16.0 for Windows (SPSS Inc., St. Louis, MO). P <0.05 was considered significant. The t-test and/or Mann–Whitney's U-test were performed to compare parametric continuous variables in independent samples between the groups, and categorical variables were analyzed using chi-square test or Fisher's exact test. To assess the diagnostic utility of SI, MSI, and ASI at varying cut-off values for the distinction between the mortality and survivor groups in patients who admitted ICU, a receiver-operating characteristic (ROC) curve was generated, and the area under the curve (AUC) was calculated. Spearman's correlation method was used to ascertain correlations between parameters. The results were stated as mean and standard deviation and/or median (minimum–maximum) for continuous variables. We used logistic regression to calculate odds ratio (OR) ±95% confidence interval (95% CI) for the association between overall mortality and events such as SBP, DBP, MAP, HR, SI, MSI, and ASI, according to corrected model for all available risk factors. Analysis of variance with Bonferroni adjustment was used for different comparisons.

In this study, G Power 3.1 program was used to calculate the statistical power at 95% CI (α=0.05) and at 90% CI (1 – β=90). The results of this analysis showed that a total of 282 patients should be sufficient for this study. However, during this time period, total of 308 patients was evaluated according to inclusion criteria.

RESULTS

Of the 610 patients hospitalized during the study period, 308 patients were included in the study based on inclusion criteria. Mean age of all patients was 68.7±16.6 years, and mean hospitalization duration was 11.4±10.2 days. The data for other variables are presented in Table 1. Mortality was observed to be 37%(114/308) among the patients included in the study. Patients were divided into three groups: 160 patients in Group 1(52%),112 patients in Group 2(36.3%), and 36 patients in Group 3(11.7%) (Figure 1). No significant age difference was noted between the groups with and without mortality (p>0.05). In patients with mortality, SBP, DBP, and MAP levels were significantly lower; HR, SI, MSI, and ASI were significantly higher than survival (p<0.05). In patients with concomitant diseases, SBP, DBP, and MAP levels were significantly lower; HR, SI, MSI, and ASI were significantly higher compared to patients without concomitant diseases (P<0.05). There was no age difference between patients with concomitant diseases (P>0.05). The age of patients admitted through inpatient treatment was observed to be significantly higher (p<0.05). According to the admission department, SBP, DBP, MAP, HR, SI, MSI, and ASI results were similar between the groups (p>0.05) (Table 2).

Multivariate logistic regression analysis was performed one step by considering mortality as a dependent variable, and SI, MSI, ASI, SBP, DBP, MAP, and HR as independent variables. SI, MSI, and ASI did affect the development of mortality (Table 3). In patients with shock, ROC analysis was performed to determine the predictive diagnostic value of SI, MSI, and ASI levels in terms of mortality. For SI, ROC-AUC was 0.640 (95% CI=0.580–0.697, p=0.0001) and cutoff value was 1.17 with Youden index with (sensitivity: 40%, 95% CI:30.3–50.3; specificity: 90.17%, 95% CI:84.7–94.2). For MSI, ROC-AUC was 0.638 (95% CI=0.577–0.695, p=0.0001) and cutoff value was 1.66 with Youden index with (sensitivity:43%,95% CI: 33.1–53.3; specificity: 91.91%, 95% CI: 86.8–95.5). For ASI, ROC-AUC was 0.621 (95% CI=0.561–0.679, p=0.0007) and cutoff value was 82.71 with Youden index with (sensitivity: 34%,95% CI:24.8–44.2; specificity:95.38%, 95% CI:91.91–98.0). ROC-AUC is shown in Figure 2.

The comparison of Groups 1,2, and 3 revealed that age was higher and HR was significantly lower in Group 3 (cardiogenic shock) compared with Group 1 and 2 but there was no statistical difference between the 3 groups (p>0.05). Hospitalization duration was significantly higher in Group 2 (hypovolemic shock) compared with the other groups (p<0.05). The results between the groups were similar in terms of SBP, DBP, MAP, SI, MSI, and ASI (p>0.05) (Table 4).

Table 1. Demographic and clinical data of all patients

Variables	Age (Years)	ICU stay (days)	SBP (mmHg)	DBP (mmHg)	MAP (mmHg)	HR (heart beat/ minute)	SI	MSI	ASI
Mean ± standard deviation	68.7±16.6	11.4±10.2	114±29	62±19	80±21	99±26	0.92±0.35	1.33±0.53	64.7±32.5
Minimum	19	2	60	25	38	43	0.28	0.46	9.4
Maximum	92	48	170	106	137	167	2	3.2	162

ICU: Intensive Care Unit, SBP: Systolic Blood Pressure, DBP: Diastolic Blood Pressure, MAP: Mean Arterial Pressure, HR: Heart Rate, SI: Shock Index, MSI: Modified Shock Index, ASI: Age Shock Index.

Table 2. Relationship between mortality, disease, and admitted service and shock indices

Variables	Mortality		P value	Comorbid diseases		P value	Admitted Department		P value
	Yes (n=114)	No (n=194)		Yes (n=228)	No (n=80)		ED (n=132)	Other services (n=176)	
Age (Years)[a]	67±18	69±15	0.182	69±14	66±21	0.144	63±20	72±11	<0.001
SBP (mmHg)[a]	105±32	120±26	<0.001	110±29	127±25	<0.001	113±25	115±32	0.578
DBP (mmHg)[a]	55±20	66±17	<0.001	61±19	66±19	0.037	65±19	60±18	0.062
MAP (mmHg)[a]	72±23	84±18	<0.001	77±21	86±18	<0.001	81±20	78±21	0.205
HR (heart beat/ minute)[a]	107±25	93±25	<0.001	105±25	81±19	<0.001	98±28	99±25	0.687
SI[a]	1.11±0.42	0.80±0.24	<0.01	1.01±0.35	0.65±0.17	<0.001	0.90±0.33	0.93±0.36	0.420
MSI[a]	1.65±0.66	1.14±0.32	<0.001	1.45±0.54	0.97±0.3	<0.001	1.27±0.48	1.37±0.56	0.091
ASI[a]	79±31±43.04	56.16±19.97	<0.001	72.05±33.01	43.86±19.51	<0.001	61.1±36.18	67.44±29.31	0.100

ED: Emergency Department, SBP: Systolic Blood Pressure, DBP: Diastolic Blood Pressure, MAP: Mean Arterial Pressure, HR: Heart Rate, SI: Shock Index, MSI: Modified Shock Index, ASI: Age Shock Index. Values of P<0.05 were considered significant. [a] Mean ± standard deviation

Table 3. Correlation of quantitative variables with mortality in univariable analysis

Variables	Mortality	
	OR (%95 CI)	P value
SBP (mmHg)	0.983 (0.986-1.0)	0.051
DBP (mmHg)	0.989 (0.976-1.001)	0.081
MAP (mmHg)	0.989 (0.979-1.0)	0.052
HR (heart beat/ minute)	1.017 (1.007-1.027)	<0.001*
SI	5.776 (2.798-11.922)	<0.001*
MSI	3.940 (2.304-6.738)	<0.001*
ASI	1.020 (1.011-1.030)	<0.001*

* Values of P<0.05 were considered significant, CI: confidence interval, OR: odds ratio, ICU: SBP: Systolic Blood Pressure, DBP: Diastolic Blood Pressure, MAP: Mean Arterial Pressure, HR: Heart Rate, SI: Shock Index, MSI: Modified Shock Index, ASI: Age Shock Index.

Table 4. Clinical and shock index data in three shock types				
Variables	Group 1 (septic shock) n=160 (52%)	Group 2 (hypovolemic shock) n=112 (36.3%)	Group 3 (cardiogenic shock) n=36 (11.7%)	ANOVA
Age (Years) [a]	68±17	67±16	74±12	0.101
ICU stay (days) [a]	8±4.2	17.8±15.3	9.7±6.4	<0.001*
SBP (mmHg) [a]	117±34	112±18	111±34	0.288
DBP (mmHg) [a]	64±18	61±19	58±22	0.190
MAP (mmHg) [a]	82±22	78±18	76±25	0.196
HR (heart beat/ minute) [a]	101±23	99±28	85±27	0.003*
SI [a]	0.93±0.34	0.9±0.27	0.92±0.56	0.780
MSI [a]	1.33±0.51	1.31±0.42	1.37±0.85	0.854
ASI [a]	64.52±29.79	62.93±28.77	71.23±50.7	0.410

* Values of P<0.05 were considered significant. [a] Mean ± standard deviation
ICU: Intensive Care Unit, SBP: Systolic Blood Pressure, DBP: Diastolic Blood Pressure, MAP: Mean Arterial Pressure, HR: Heart Rate, SI: Shock Index, MSI: Modified Shock Index, ASI: Age Shock Index.

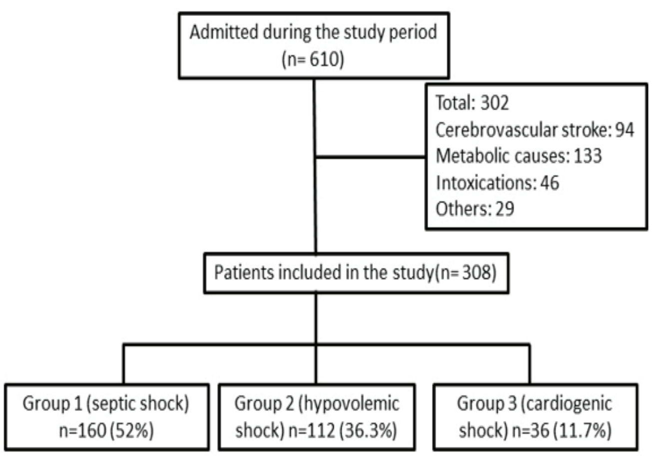

Figure 1. Flow chart of patients included in the study

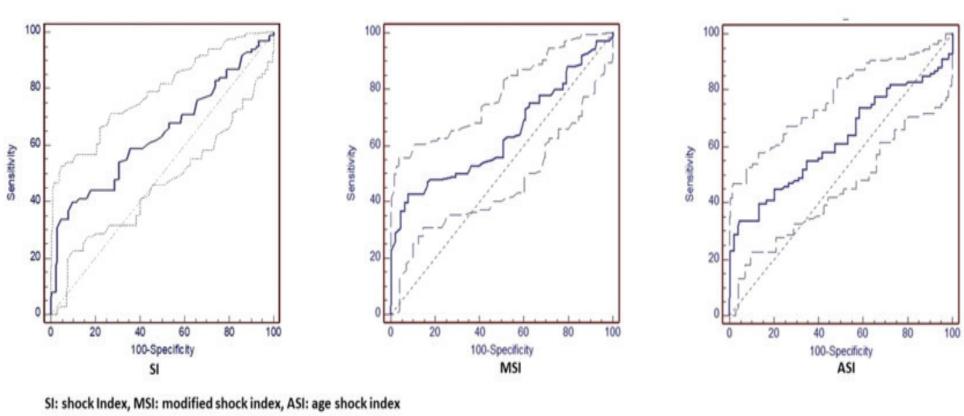

Figure 2. Receiver operating characteristics curve for SI, MSI, and ASI predicting mortality

DISCUSSION

In the present study, all three shock indices were observed to be high in the groups that were at risk for shock during ICU hospitalization. Elevated shock index was associated with concomitant disease and mortality. Patients with cardiac diseases were older, with lower HR. In addition, hospitalization duration was longer in the hypovolemic shock group. In terms of predicting mortality, all three shock indices were similar for predicting mortality in patients with shock. Many studies are conducted to assess the predictive ability of SI for mortality and to compare it with other potential predictors, such as conventional vital signs.[6] In the event of unscheduled transfers from the emergency department to the ICU, physiological variables are typically used. However, changes in vital signs may not accurately reflect the patient's clinical severity.[13] Aftershock index was defined, studies investigating the relationship between short- and long-term clinical results and SI were conducted.[14,15] Shock index has been proposed as a marker that could be used to estimate the severity of shock. In most of the studies, it has been reported that the use of SI could be a valuable tool in suspicious cases, despite normal HR and blood pressure.[4,7,11] In several studies investigating sepsis, hemorrhage, and cardiovascular diseases, SI has been observed to be an important indicator of mortality in patients in the emergency department.[5,9,10,14] SI is commonly used in the emergency department to predict patients' clinical outcomes. In this sense, our study is among the few studies comparing three different shock indices in ICU. In healthy adults, SI is typically in the range of 0.5–0.7. SI value of >0.9 has been found to be associated with increased mortality.11 In addition, it was found that SI values >0.85 could help clinicians as a determinant of unscheduled transfers to ICU.[13] Considering that shock indices are easily measured at the bedside, they facilitate clinicians to perform prompter patient interventions.[4] The use of SI alone is limited because of its complexity in the pathophysiology of patients with shock.[16] Therefore, studies have been conducted for patients to provide better information to clinicians, thereby enabling a better predictability of mortality. For this purpose, Liu et al. have proposed MSI. MSI was observed to be superior to SI in predicting the mortality of patients in the emergency department.[5] Further studies were conducted to find better indices to predict mortality in patients with shock, and ASI was found to be superior to SI and MSI in predicting mortality.[6,17] Studies on shock indices were initially conducted among patients with shock in the emergency department, and fewer studies were conducted with patients admitted to the ICU.[4,12] Semerci et al. have demonstrated that SI did not have any effect on mortality in patients with gastrointestinal bleeding.[18] Based on our results, SI, MSI, and ASI were found to be higher in patients with mortality and concomitant diseases. In addition, three different shock indices were not found to be superior to each other in predicting mortality. Elevated MSI (>1.3) during early sepsis has reportedly been associated with myocardial dysfunction.[12] In the ICU, MSI elevation (>1.8) within the first 24 h is associated with an increased risk of mortality in critically ill patients.[4] In geriatric patients with trauma, SI, MSI, and ASI were found to be higher than 0.84, 1.14, and 64, respectively, in the event of mortality.[19] In the present study, cutoff value for predicting mortality was 1.17 for SI, 1.66 for MSI, and 82.71 for ASI. In addition, all three shock indices were found to be similarly significant in predicting mortality. In certain studies, it has been reported that MSI was superior to SI, and ASI was superior to MSI in predicting mortality.[6,7,19] The reason for the different cutoff values for mortality and the superiorities of shock indices against each other may be associated with the underlying disease causing shock and the number of patients. In other studies, shock indices were not evaluated due to the underlying disease. Based on our results, all three shock indices were higher in cases with underlying diseases. In addition, if the patient was in hypovolemic shock, hospitalization duration was longer. In patient with hypovolemic shock, hospitalization duration may be prolonged due to postoperative complications or secondary complications associated with trauma, gunshot wound, and coagulopathy.[20]

Limitations

Our study has several limitations. Because of the retrospective design of our study, the need for crystalloid and blood transfusions, inotropic support, the type and rate of fluid administered in fluid resuscitation as well as costs and complications were not evaluated. Our results are the first study shown in ICU, which has a very high mortality but not very strong sensitivity.

CONCLUSION

In conclusion, high shock indices (SI, MSI, and ASI) were found to be associated with mortality in the present study. The similarity of AUC values in three different shock indexes shows similar effect in showing mortality. AUC shows a modest predictive capability for prediction of mortality by shock indexes. Moreover, shock indices were higher in patients with concomitant diseases, and hospitalization duration was longer in patients with hypovolemic shock. Considering that shock indices are easily measured at the bedside, we believe that using shock indices during patient admission to ICU could provide more objective information to clinicians about the patient's clinical course and survival probability. Larger prospective studies that include patients in the lower categories are needed to determine cutoff values of shock indices in predicting mortality and investigate different indices in terms of their superiority against each other.

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