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Original Article

Do Shock Index and Modified Shock Index Have Any Prognostic Value in Severely Ill Elderly, Medical Patients with Multiple Comorbidities?

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SUMMARY

Background: This study is conducted to see if calculating admission shock index (SI) or modified shock index (MSI) are useful to predict the 28 days mortality in geriatric patients admitted to intensive care unit (ICU) for medical reasons.
Methods: 446 patients over 60 years old with at least two comorbidities besides the reason for admission were included in this retrospective study. The first ICU admission data of systolic blood pressure (SBP), diastolic blood pressure (DBP), mean arterial pressure (MAP), Glascow Coma Score, Acute Physiological and Clinical Health Evaluation-II Score, demographics and first laboratory and blood gas analysis results besides calculated SI (Heart rate/SBP) and MSI (Heart rate/MAP) were recorded. The patients were divided in two groups, according to the 28-days survival. The predictive value of SI and MSI and their cut off values for the 28th day mortality were detected. The impact of variables like serum creatinine and lactate levels were also assessed. Univariate and multivariate logistic regression analysis were performed to assess the impact of variables on outcome.
Results: Univariate regression analysis showed that increased risk of 28-day mortality associated with SI > 1.09 (Odds ratio (OR) = 4.15, 95% confidence interval (CI): 2.63–6.55) fold), MSI > 1,4 (OR = 3.76, 95% CI: 2.46–5.75), serum creatinine (OR = 1.27 for each 1 mg/dL increase, 95% CI: 1.12–1.44), and serum lactate (OR = 1.13 for each 1 mmol/L increase, 95% CI: 1.05–1.21.
Conclusion: SI and MSI indices can be used as a practical predictive measurement of mortality in critically ill elderly medical patients.

1. Introduction

Clinicians always need better predictors of acute life-threatening conditions to provide best initial therapeutic strategy. Shock index (SI) is developed as a hemodynamic stability indicator.[1] It is defined as heart rate (HR) divided by systolic blood pressure (SBP). It has been shown to be a better marker for assessing severity of shock of any kind than HR and BP alone. It has utility not only in trauma patients and acute hemorrhage[2–5] but also many clinical settings like sepsis,[6,7] pneumonia,[8,9] pulmonary embolism,[10] obstetrics,[11] myocardial infarction,[12] stroke,[13] emergency intubations[14] and intensive care unit (ICU) transfers.[15]

When Modified Shock Index (MSI) was proposed,[16] it was postulated that as diastolic blood pressure (DBP) fell earlier than SBP, mean arterial pressure (MAP) could be a more accurate predictor of disease severity and mortality. Some studies used and compared SI and MSI,[14,17–20] while some others showed that adding parameters like age, Glasgow Coma Scale (GCS) score, lactate levels, central venous pressure, and other physiologic markers make a better prediction of outcome than with one individual vital sign in the critically ill patient.[9,21–25]

Poorly controlled chronic diseases are more likely to be seen in elderly population. In the absence of significant functional reserves, exposure to sustained physiologic stress may result in acute decompensation and organ failure.[26] In an elderly patient with multiple comorbidities, it is also difficult to differentiate the primary reason of decompensating organ functions, and in the face of sustained hemodynamic imbalance despite the interventions in emergency department or in the wards, the situation may even be more complex.

This study was hypothesized that whether the measurements after the patients admitted to the ICU could be predictors of 28th-day all-cause ICU mortality in elderly medical ICU patients with multiple comorbidities. Unlike the previous studies that specified a certain disorder, as it is usually difficult to limit the dysfunction to only one system in the geriatric patient in the urgent situation before making a broader screening, we included the whole non-surgical group.

2. Materials-methods

This retrospective observational cohort study was performed in a 21 bed medical/surgical tertiary ICU of a university affiliated training and research hospital between January 2017–January 2018. The study was approved by the local scientific committe of the hospital. All data were collected retrospectively from the hospital database (Picture Archiving and Communication System).

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2.1. Patients

Inclusion criterions: Patients ≥ 60 years of age whom admitted for acutely decompensated medical reasons (cardiovascular, respiratory, renal, neurologic, and metabolic); and who have at least two diagnosed comorbidities accompanying the reason for ICU admission. *Exclusion criterions*: Trauma patients, patients who admitted for postoperative care/surgical complications, or after an acute intracranial event; patients whose complete data were missing; patients who were known to use antihypertensive medications; and patients in whom the vasopressor treatment had been started before the ICU admission.

2.2. Recorded data

Patients' demographics, comorbidities, Acute Physiological and Clinical Health Evaluation (APACHE II) score, Glascow Coma Score (GCS), length of stay-mechanical ventilation (LOS-MV), length of stay-ICU (LOS-ICU) were recorded. The first hemodynamic measurements (Systolic blood pressure [SBP], diastolic blood pressure [DBP], mean arterial pressure [MAP]; heart rate [HR]) (Non-invasive; manual cuff and sphygomanometer or automated oscillometric device; electrocardiogram or pulse oximetry) were recorded soon after the patient admitted and monitorized in the ICU. Admission levels of serum creatinine and lactate levels along with the other laboratory results and arterial blood gases were recorded.

2.3. Calculations

Shock Index: HR per minute over SBP[1]

Modified Shock Index: HR per minute over MAP[16]

28th day outcome was taken as the study end point.

The patients were divided in two groups, according to the 28-days survival.

2.4. Statistical analysis

IBM SPSS Statistics 22 program was used. Whether or not the parameters were normally distributed was analyzed with Shapiro Wilks test. Student–t test was used for the comparison of the quantitative data and normally distributed variables as well as the complementary statistical methods (mean, standard deviation [SD], frequency). For the comparison of not normally distributed variables Mann Whitney U test (median, interquartile range [IQR]), and for the comparison of normally distributed variables Paired Samples t test were used. The qualitative data was compared with Chi square test. The correlation between the normally distributed and not normally distributed parameters were assessed using Pearson Correlation Analysis, and Spearman's rho Correlation Analysis. Univariate and multivariate logistic regression analysis were performed to assess the impact of variables on outcome. Prognostic performances of SI, MSI, APACHE II, number of comorbidities, admission lactate and serum creatinine levels were assessed for 28th day all-cause mortality, and the correlation of these variables with the LOS-ICU were included in the model. The ROC-AUC (Receiver operating characteristics-area under curve) was built to evaluate the cut-off points of SI and MSI in relation to 28 days all-cause mortality. The cut-off values of SI and MSI were detected for the study subgroups also, for the age of 60–80 and > 80.

To discriminate the predictive power of these indices, the ROC curves were compared. Two sided values of $p < 0.05$ were considered as statistically significant.

3. Results

During the study period 1220 patients were admitted to ICU, and finally 446 patients (207 male, 46%) were enrolled with the mean age of 77 (60–99). The all-cause mortality on the study end point (28th-day) was 49.6% (221/446).

Hypertension, diabetes mellitus, coronary artery disease, chronic obstructive airway disease, arrhythmias, previous cerebrovascular accident, chronic renal disease, malignancies were the most common comorbidities, and the number of comorbidities did not differ between survivors and non-survivors (2(2-3) median (IQR)) SI, MSI, APACHE II, lactate and creatinine levels at the admission showed significant effects on 28th day all cause mortality (Table 1).

Univariate and multivariate regression analysis were both summarized in Table 2. The univariate regression analysis (Table 2, part A) was done for quantitative variables including SI above 1.09, MSI above 1.4, serum creatinine levels for each 1 mg/dl increase and serum lactate levels for each 1 mmol/L increase. The odds ratios of the analysed parameters were 4.15; 3.76; 1.27 and 1.13 fold greater respectively in the non-survivors ($p < 0.001$).

Multivariate regression analysis were also shown in Table 2; for the same amount of increase in serum creatinine and lactate values with SI above 1.09 (part B) and MSI above 1.4 (part C) individually. The multivariate analysis of 28 day mortality with SI (part B) showed nearly similar odds ratio of multivariate analysis of 28 day mortality with MSI (part C).

There was a strong correlation between SI and MSI both in survivor and nonsurvivor groups ($r = 0.91$, $r = 0.95$; $p < 0.01$).

There was a weak positive correlation between MSI and APACHE II (MAP is used as systemic arterial pressure surrogate) in survivors ($r = 0.17$, $p = 0.011$) and non-survivors ($r = 0.14$, $p = 0.042$). No correlation was found between APACHE II and SI ($r = -0.01$, $p = 0.98$).

Table 1
Study variables and their relation with 28 days outcome.

Variables	28th days outcome		p
	Survivors, N	Non-survivors	
APACHE II mean (SD)	19 (7)	28 (7)	< 0.001#
SI, median (IQR)	0.76 (0.76–0.99)	0.93 (0.7–1.3)	< 0.001*
MSI, median (IQR)	1.12 (0.90–1.35)	1.34 (1.03–1.9)	< 0.001*
LOS-MV (days), median (IQR)	1 (1–4)	3 (1–5)	< 0.001*
LOS-ICU (days), median (IQR)	4 (3–10)	4 (2–10)	= 0.19*
Comorbidities (number), median (IQR)	2 (2–3)	2 (2–3)	= 0.23*
Creatinine (mg/dL), mean (SD)	1.68 (1.38)	2.32 (1.99)	< 0.001#
Lactate (mmol/L) mean (SD)	2.33 (4.09)	3.74 (3.88)	< 0.001#

Student t Test, mean (SD).

* Mann Whitney U test, median (IQR; Interquartile range); p < 0.05 significant.

Table 2
The univariate and multivariate analysis of 28 day mortality of patients.

	Odds ratio	Confidence Interval 95%		p
		Lower	Upper	
A-Univariate analysis				
Shock index > 1.09	4.15	2.63	6.55	< 0.001
Modified Shock index > 1.40	3.76	2.46	5.75	< 0.001
Creatinine*	1.27	1.12	1.44	< 0.001
Lactate**	1.13	1.05	1.21	< 0.001
B-Multivariate analysis for SI, creatinine and lactate				
Shock index > 1.09	3.49	2.18	5.6	< 0.001
Creatinine*	1.23	1.08	1.39	< 0.001
Lactate**	1.08	1.01	1.15	0.024
C-Multivariate analysis for MSI, creatinine and lactate				
Modified Shock index > 1.40	3.31	2.13	5.13	< 0.001
Creatinine*	1.24	1.09	1.41	< 0.001
Lactate**	1.08	1.01	1.15	0.018

* each 1 mg/dl increase; ** each 1 mmol/L increase.

The analysis of ROC-AUC of ICU admission SI and MSI for predicting 28th day all-cause mortality is shown in Table 3.

The data for subgroup analysis were summarised in Table 4. The SI, MSI, serum creatinine and lactate levels and the numbers of comorbid diseases were similar in aged 60–80 and > 80 groups. When the age subgroups were analysed for the studied parameters according to the 28 days mortality, the age group between 60–80 years old had significantly higher values of serum creatinine and lactate values in non-survivors than survivors. Whereas patients aged above 80 had similar serum creatinine and lactate levels both in non-survivors and survivors (Table 5).

Table 3
Area under curve of ROC for shock index and modified shock index of 28 day of mortality.

	AUC	Confidence interval 95%		p value	Cut off	Sens %	Speci %
		Lower	upper				
SI	0.65	0.60	0.70	<0.001	1.09	41.6	85.3
MSI	0.65	0.60	0.70	<0.001	1.4	47.1	80.9

SI: Shock index; MSI: Modified shock index; AUC: Area under curve.

4. Discussion

This study found that the elderly patients in the ICU of 28th day mortality risk increased by 4.15 fold with SI over 1.09 and by 3.76 fold with MSI over 1.4. The serum creatinine over 1.2 mmol/L and lactate level over 2 mmol/L are increased mortality nearly 1.27 and 1.13 fold respectively. The levels of serum creatinine and lactate showed significant increase for non-survivors in age 60–80 group but not at the age of above 80.

Studies evaluating the usefulness of SI demonstrated that a cut-off value > 0.9 is accurate at predicting mortality in critically ill patients. MSI was developed by Liu et al. They replaced MAP instead of SBP in the equation and said that MAP could best represent tissue perfusion status and was an accurate predictor of disease severity better than SI.[16] The higher mortality was seen with MSI < 0.7 meaning the patient is in the hyperdynamic state and or above 1.3 which showed the hypodynamic state and high probability of ICU admission and death. SI and MSI both showed value in predicting outcomes among ICU patients with different pathologies.[16–20,27,28]

In the present study, the selected patients were 60 years old and older, who had at least two or more comorbidities presenting a

Table 4
The comparison of age subgroups for shock index, modified shock index, serum creatinine and lactate levels.

	Age 60–80 (n = 242)	Age > 80 (n = 204)	p
Shock Index, median (IQR)	0.84 (0.65–1.16)	0.80 (0.63–1.11)	0.36#
Modified Shock Index, median (IQR)	1.21 (0.98)	1.19 (0.94–1.55)	0.69#
Comorbidities, median (IQR)	2 (2–3)	2 (2–3)	0.83#
Creatinine, mg/dl, mean (SD)	1.86 (1.62)	2.16 (1.86)	0.07¥
Lactate mmol/L, mean (SD)	3.15 (4.03)	2.89 (4.08)	0.50¥
Mortality in 28 days, n (%)	114 (47)	107 (53)	0.26*

* Chi Square test, # Mann Whitney U test, ¥ Student T test.

Table 5.
Age subgroups comparison of shock index, modified shock index, serum creatinine and lactate levels according to survivors and non-survivors.

	Age 60–80		p	Age > 80		p
	Survivors (n = 128)	Non-survivors (n = 114)		Survivors (n = 97)	Non-survivors (n = 107)	
Comorb. median (IQR)	2 (2–3)	2 (2–3)	0.79*	2 (2–3)	2 (2–3)	0.21*
Creatinine (mg/dl), mean (SD)	1.39 (1.03)	2.39 (1.96)	<0.001#	2.06 (1.67)	2.25 (2.02)	0.45#
Lactate (mmol/L), mean (SD)	2.3 (3.7)	4.1 (4.2)	<0.001#	2.4 (4.6)	3.4 (3.5)	0.08
SI median (IQR)	0.77 (0.63–1.00)	0.96 (0.70–1.37)	<0.001*	0.75 (0.6–0.98)	0.89 (0.65–1.31)	<0.001*
MSI median (IQR)	1.12 (0.9–1.35)	1.35 (1.06–1.93)	<0.001*	1.14 (0.92–1.35)	1.29 (0.99–1.79)	0.006*

* Mann Whitney U test, # Student T test.

severely ill, complex medical patient. These patients are seen in emergency departments and hospital wards in increasing number. They often have poor condition of health, like dehydration or malnutrition and/or some degree of organ dysfunction as well as septic situations those may lead to respiratory and hemodynamic imbalance, and deranged tissue perfusion. Once patient's admission of ICU is regarded necessary, systemic arterial pressures and heart rate are usually abnormal, despite of all the efforts to stabilize the situation in the emergency department or in the wards. In this condition, it is worth to clarify if the SI or MSI might be useful indices for the prediction of the outcome.

According to the findings of this study, SI and MSI were significantly high in non-survivor group, leading us to conclude that SI and MSI can be used to predict the mortality of the elderly patients similar to the younger population. Our study group did not include trauma or patients with intracranial event, in whom a hyperdynamic state and low SI or MSI (< 0.7) might be seen as an index of poor outcome, instead, they were non-surgical elderly group in whom mostly a hypodynamic state was prominent.

The high majority of the measurements of the indices were done usually after the initial therapeutic interventions, which may show similarity with the study of Yussof et al. who compared the initial SI and SI after two hours of resuscitation. In their study, they recorded that the SI above 1 after two hours showed 80.8% sensitivity and 79.2% specificity for predicting the mortality.[29] Wira et al. studied on the septic patients in emergency department with sustained SI elevation. These patients had more organ dysfunction at presentation and tended to require more vasopressor use over the next 72 hours, Wira suggested that the sustained SI might be more useful as a predictor of the clinical course of these patients.[30]

In this study, the first measurements were taken soon after the patients arrived ICU, the previous values were not taken into account, but as the reason of admission was usually the deteriorated clinical condition that was mostly accompanied by the worsened parameters, there was a high possibility of sustained SI elevation in our study group as well.

There are a few studies evaluating the predictive value of SI or MSI in the literature for the geriatric age group. In this age group, the usefulness of SI or MSI has been discussed because of the limited physiologic reserve leading to a blunted response to acute injury or critical disease, and also usage of antihypertensive-antiarrhythmic medications in these patients.[31] Salottolo et al did not found any predictive value of SI > 1 in geriatric trauma patients, venous lactate was superior in detecting the occult hypoperfusion in this study.[32] However, there are studies showed that SI and MSI were increased above the previously detected cut-off values and the predictive values of these indices were high in geriatric trauma, sepsis, pneumonia groups.[3,6,18,33]

To predict the mortality, SI, MSI and Age Shock Index (Age*SI) were validated in geriatric trauma group, and the percentage of unstable patients who died was found to be 36.6% based on the SI; 38.6% based on the MSI and 69.4% based on the age SI. The cut-off values were 0.8 for the SI, and 0.9 for the MSI.[18]

Similar associations were found also in non-trauma settings. Geriatric patients with influenza infection showed increased mortality if they had SI of > 1 with high specificity and negative predictive value.[33] In oldest elderly patients admitted with acute medical problem, shock index above 1 was found to be independently related with death.[25]

SI and MSI were highly correlated in our patients. No superiority was detected between the two indices in terms of the sensitivity and specificity.

Besides SI and MSI, we also found a predictive value of admission lactate and serum creatinine levels. Both markers were found independently related with the mortality, but the number of comorbidities did not show any difference between the survivors and non-survivors (Table 1).

Rady et al. evaluated the elevated SI along with central venous oxygen saturations and lactate levels in septic patient group in ICU and suggested that using three parameters together may identify patients with persistent cardiac dysfunction and/or inadequate resuscitation.[7] In severe sepsis group, it was stated that normal SI predicted the absence of elevated lactate levels and would be useful in triage situations.[6]

Regarding the subgroups of aged 60–80 and > 80; the serum creatinine and lactate levels showed statistically and clinically significant increases in the non-survivors of the 60–80 age group, but above the age 80, the rises in these levels were not pronounced in non-survivors (Table 5). This may be explained by the already higher baseline levels of creatinine and lactate in the critically ill oldest elderly, leading to an insignificant difference between the survivors and non-survivors of this age group.

5. Limitations

This is a single center retrospective study. The information about medications was usually taken from the patient himself/herself, therefore may be wrong. The analysis was performed in the general medical population, assuming that the SI provides an integrated assessment of cardiovascular responses in critically ill geriatric patients. The results may reflect a complex scene rather than a specific feature of a disease.

6. Conclusion

SI and MSI can be used as practical predictive measurements of mortality in elderly critically ill medical patients. Like some studies proposed to add some important parameters of acute illness to SI or MSI, regarding values like lactate and creatinine on admission would help to estimate outcome more precisely especially between the ages of 60–80. For the age group of above 80 with multiple comorbidities, either SI or MSI can be more predictive of mortality.

Conflicts of interest

None.

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