

A Comparative Study on Predictive Validity of Modified Shock Index, Shock Index, and Age Shock Index in Predicting the Need for Mechanical Ventilation among Sepsis Patients in a Tertiary Care Hospital

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Abstract

Introduction: The shock index (SI), modified shock index (MSI), and age multiplied by SI (ASI) are used to assess the severity of shock. They are also used to predict the mortality of trauma patients, but their validity for sepsis patients is controversial. The aim of this study is to assess the predictive value of the SI, MSI, and ASI in predicting the need for mechanical ventilation after 24 h of admission among sepsis patients. **Methods:** A prospective observational study was conducted in a tertiary care teaching hospital. Patients with sepsis (235) diagnosed based on systemic inflammatory response syndrome criteria and quick sequential organ failure assessment were included in the study. The need for mechanical ventilation after 24 h is the outcome variables MSI, SI, and ASI were considered as predictor variables. The utility of MSI, SI, and ASI in predicting mechanical ventilation was assessed by receiver operative curve analysis. Data were analyzed using coGuide. **Results:** Among the study population, the mean age was 56.12 ± 17.28 years. MSI value at the time of disposition from the emergency room had good predictive validity in predicting mechanical ventilation after 24 h, as indicated by the area under the curve (AUC) of 0.81 ($P < 0.001$), SI and ASI had fair predictive validity for mechanical ventilation as indicated by AUC (0.78, $P < 0.001$) and (0.802, $P < 0.001$), respectively. **Conclusion:** SI had better sensitivity (78.57%) and specificity (77.07%) compared to ASI and MSI in predicting the need for mechanical ventilation after 24 h in sepsis patients admitted to intensive care units.

Keywords: Emergency medical services, intensive care, mechanical ventilation, shock

INTRODUCTION

Early identification and early intervention are the cornerstones in the management of shock in sepsis patients, which is one of the leading medical emergencies. Between 1995 and 2015, there has been a worldwide incidence of 437 cases/100,000 as per a retrospective study of an international database.^[1] The current incidence of the disease is increasing.^[2,3] The mortality associated with sepsis is directly proportional to the severity of the disease.^[4] The morbidity and mortality associated with sepsis and disease progression of sepsis can be restrained by early identification of sepsis and management of the same. In addition, there is a reduction in financial burden also.^[5-7] The initial hour of identification and management for sepsis starts from the time patient arrives at triage as per surviving sepsis campaign 2018.^[8] One of the common presenting

symptoms in triage is fever which is seen in many spectra of diseases; however, it is the main clue in clenching diagnosis in 55%–76% of sepsis patients.^[9,10] The signs of sepsis is not easily distinguishable from other uncomplicated febrile illness as it is very subtle, and not specific. Sepsis is difficult to diagnose in triage and the emergency department where time is a main constraint.^[11-14]

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In view of time being the main factor in the identification and treatment of sepsis, there is a need for a screening method that identifies the signs early and thereby halts the disease progression.

By dividing heart rate (HR) over systolic blood pressure (SBP), SI is calculated by dividing heart rate over Systolic blood pressure. MSI is derived by dividing heart rate over MAP. We arrive at a modified shock index (MSI). The SI has been used as a tool in suspected septic patients to identify hyperlactatemia and mortality, which yielded promising results as per two Emergency department (ED) observational studies.^[15,16] The SI is a weak predictor. In terms of sensitivity and specificity, the MSI was a better predictor of mortality as per studies.^[17,18]

This study was conducted with the aim of assessing the predictive validity of MSI, SI, and age SI (ASI) in predicting the need for mechanical ventilation among sepsis patients admitted to the intensive care unit (ICU) of a tertiary care hospital.

METHODS

A prospective observational study was conducted in the department of emergency medicine. The data collection for this study was conducted between January 2020 and December 2020. Data confidentiality was ensured, and all patients signed informed written consent. The study participants were patients presenting with features of sepsis in the emergency department. The patients were assessed at baseline and after 24 h of admission for the need for mechanical ventilation using a various scores. The sample size was calculated assuming the expected mortality of sepsis patients as 19.8% as per Jayaprakash *et al.*'s study.^[19] The predictive validity was assessed by the area under the curve (AUC) value of 0.75 against a null value of 0.5, 95% power, and 5% two-sided alpha error. As per the above-mentioned calculation, the required sample was 107. To account for a loss to follow-up of 10%, another 11 subjects were included in the study.

The study participants were sepsis patients diagnosed by systemic inflammatory response syndrome (SIRS) criteria and quick sequential organ failure assessment (qSOFA) score. Patients above 18 years were included in the study. Those who were pregnant, on immunosuppressive drugs and those with a history of trauma were excluded from the current study. Baseline investigations such as complete blood count and physical examination were done. SIRS was considered when fulfilling at least two of the following four criteria: "fever $>38.0^{\circ}\text{C}$ or hypothermia $<36.0^{\circ}\text{C}$, tachycardia >90 beats/min, tachypnea >20 breaths/min, and leukocytosis $>12 \times 10^9/\text{L}$ or leukopenia $<4 \times 10^9/\text{L}$." The qSOFA score is one of the available, easy-to-use bedside tools that can be used to diagnose suspected sepsis patients who are at high risk of having a poor outcome when outside the ICU. It consists of three criteria, each with one point score: "low blood pressure (SBP ≤ 100 mmHg), increased respiratory rate (≥ 22 breaths/min), or altered mental status (Glasgow Coma Scale <15)." MSI is calculated by "dividing HR over

MAP." Patients with sepsis are identified mainly based on SIRS criteria. qSOFA is taken into consideration to parallelly prognosticate the patient. Patients' need for mechanical ventilation was considered an outcome of interest. Patients with severe sepsis required mechanical ventilation and a longer duration of ICU care. The admission SI, MSI, and ASI were calculated for each patient. To make these calculations, the following formulas were used: SI (defined as HR/SBP), MSI (defined as HR/MAP), and ASI (age $\times$ SI).

Statistical methods

Mechanical ventilation was considered as outcome categorical parameters reported as count and proportions where age, SI, MSI, and ASI as continuous variables compiled using mean, standard deviation, and median interquartile range (IQR).

The utility of MSI, SI, and ASI in predicting mechanical ventilation was assessed by receiver operative curve (ROC) analysis. The area under the ROC curve, along with its 95% confidence interval (CI) and *P* value, is presented. Based on the ROC analysis, the cutoff was decided for each index individually. The sensitivity, specificity, predictive values, and diagnostic accuracy of the screening test with the decided cutoff values along with their 95% CI were presented. *P* < 0.05 was considered statistically significant. Data were analyzed using coGuide, V1.0.3 (BDSS Corp. Bangalore, Karnataka, India).^[20]

coGuide was used for the statistical analysis.

RESULTS

A total of 235 subjects were included in the final study.

Among the study population, the mean age was 56.12 ± 17.28 years. One hundred and thirty-nine (59.15%) were male and the remaining 96 (40.85%) participants were female. The mean systolic and diastolic BP were 99.69 ± 20.8 mmHg and 67.08 ± 12.77 mmHg, respectively. The HR mean value of study participants was 104.36 ± 18.5 beats/min [Table 1].

Among study participants, 11.06% (26 out of 235) required mechanical ventilation in the emergency room (ER) (within 24 h). About 59.6% of participants were discharged after 72 h and no death was declared in ER. The mean value of MSI was 1.25 ± 0.33 , the median and IQR of SI were 1.02 (0.85–1.29) and ASI was 59.16 (41.28, 75.63) [Table 2].

Table 1: Summary of baseline parameters in the study population (*n*=235)

Parameter	Mean $\pm$ SD
Age (years)	56.12 $\pm$ 17.28 (20-95)
Gender, <i>n</i> (%)	
Male	139 (59.15)
Female	96 (40.85)
Systolic BP mm of Hg	99.69 $\pm$ 20.8 (50-154)
Diastolic BP mm of Hg	67.08 $\pm$ 12.77 (30-96)
HR base line (bpm)	104.36 $\pm$ 18.5 (61-162)

SD: Standard deviation, BP: Blood pressure, HR: Heart rate

Among participants, the majority of 53.52% had type 2 diabetes mellitus, followed by chronic kidney disease 10.21%. The major source of sepsis was respiratory with 85 (36.2%) followed by abdomen (17%), genito urinary (16.2%), and systemic (15.7%) where other sources were musculoskeletal, neuroinfection, and cardiac with minor percentages [Table 3].

MSI value at the time of disposition from ER had good predictive validity in predicting mechanical ventilation after 24 h, as indicated by AUC of 0.81 ($P < 0.001$), SI and ASI had fair predictive validity for mechanical ventilation as indicated by AUC (0.78, $P < 0.001$) and (0.802, $P < 0.001$), respectively [Figure 1].

The MSI value at the time of disposition from ER of 1.35 and above had sensitivity of 75% in predicting mechanical ventilation after 24 h. Specificity was 74.27% and the total diagnostic accuracy was 74.35%. The SI value more than equal to 1.25 had sensitivity of 78.57% in predicting mechanical ventilation after 24 h. Specificity was 77.07% and the total diagnostic accuracy was 77.25%. The ASI value at cutoff of 70.11 had sensitivity of 75% in predicting the need for mechanical ventilation after 24 h. Specificity was 72.81% and the total diagnostic accuracy was 73.07% [Table 4].

DISCUSSION

The SI has been widely used in different clinical settings for the assessment of hemodynamic instability and prediction or estimation of outcomes. It was first introduced in 1967 and has proven to be more sensitive than either HR or SBP to detect hemodynamic compromise.^[21,22] The SI represents a very convenient, noninvasive tool to aid in the assessment of potentially unstable patients, with the advantage that it is very easy to calculate and represents an additional expense to patients.

The normal SI was originally determined to be in the range of 0.5–0.7,^[22,23] but different thresholds have also been used, for example, 0.9, 1.0, or higher.^[24] A higher SI cut off loses

sensitivity and gains specificity; for this reason, some have proposed that a cutoff point of 1.0 might represent a reasonable balance between specificity versus sensitivity with the advantage of providing more impact in its ability to predict mortality.^[25] In this current study, we have used a cutoff of SI of more than 1.3 as per the ROC analysis obtained for the dataset.

The SI has been applied in different clinical settings. It was originally used as an early evaluation of the circulatory status in patients with trauma and suspected hypovolemic shock.^[21]

Since then, it has been applied in other areas; Zhang *et al.* Reported that an elevated SI (>0.7) was associated

Table 2: Summary of investigations and scores in the study population ($n=235$)

Parameter	Summary, n (%)
Inotropes in ER (the first 24 h)	84 (35.74)
Inotropes after 24 h	20 (8.5)
Inotropes after 72 h	6 (2.6)
Mechanical ventilation in ER (the first 24 h)	26 (11.06)
Mechanical ventilation after 24 h	28 (11.97)
Mechanical ventilation after 72 h	13 (5.53)
Discharged after 72 h	140 (59.6)
Patient stepdown from ICU/HDU after 24 h	114 (48.51)
Stepdown to ward at 72 h	114 (48.51)
Death declared in ER (no)	235 (100)
Timing of death ($n=7$) (h)	65.14 $\pm$ 11.71 (48-72)
Modified shock index at the time of disposition from ER, mean $\pm$ SD	1.25 $\pm$ 0.33
Modified shock index value on arrival to ER, mean $\pm$ SD	1.47 $\pm$ 1.11
qSOFA score Namaste, mean $\pm$ SD	1.56 $\pm$ 0.57
Shock index	1.02 (0.85-1.29)
Age shock index	59.16 (41.28-75.63)

ER: Emergency room, qSOFA: Quick sequential organ failure assessment, SD: Standard deviation, ICU: Intensive care unit, HDU: High dependency units

Table 3: Summary of chief complaints and source of sepsis in the study population ($n=235$)

Parameter	Summary, n (%)
CKD	24 (10.21)
Chronic liver disease	4 (1.7)
Congestive cardiac failure	3 (1.28)
DM type 1	1 (0.43)
DM type 2	64 (27.2)
Atrial fibrillation (no)	4 (100)
Comorbidities	103 (43.8)
Source of sepsis	
Respiratory	85 (36.2)
Abdomen	40 (17)
Genito urinary	38 (16.2)
Systemic	37 (15.7)
Musculoskeletal	21 (8.9)
Neuro infection	12 (5.1)
Cardiac	2 (0.9)

DM: Diabetes mellitus, CKD: Chronic kidney disease

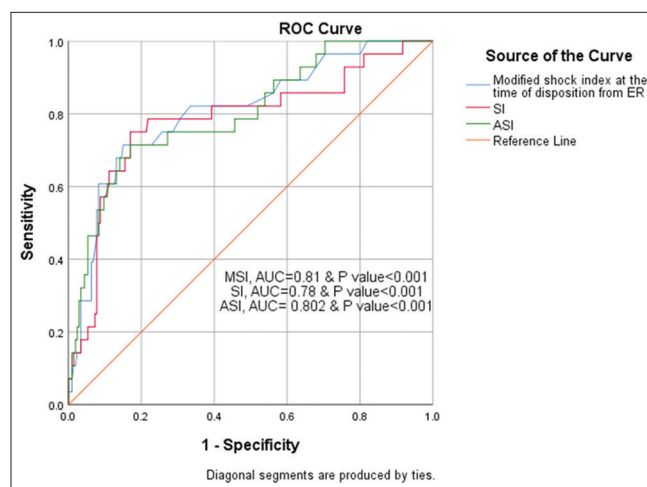


Figure 1: ROC analysis of predictive validity of different scoring systems in predicting mechanical ventilation after 24 h in study population ($n = 235$). ROC: Receiver operative curve

Table 4: Predictive validity of modified shock index, shock index, and age shock index in predicting mechanical ventilation after 24 h (n=234)

Parameter	MSI >1.35	SI >1.25	ASI >70.11
Sensitivity	75 (55.12-89.30)	78.57 (59.04-91.70)	75 (55.12-89.30)
Specificity	74.27 (67.73-80.09)	77.07 (70.70-82.64)	72.81 (66.19-78.76)
False positive rate	25.72 (19.90-32.26)	22.92 (17.35-29.29)	27.18 (21.23-33.80)
False negative rate	25 (10.69-44.87)	21.42 (8.296-40.95)	25 (10.69-44.87)
Positive predictive value	28.37 (18.50-40.05)	31.88 (21.17-44.20)	27.27 (17.74-38.61)
Negative predictive value	95.62 (91.19-98.22)	96.34 (92.20-98.64)	95.54 (91.02-98.18)
Diagnostic accuracy	74.35 (68.26-79.82)	77.25 (71.32-82.47)	73.07 (66.91-78.64)

SI: Shock index, MSI: Modified SI, ASI: Age SI

with increased in-hospital mortality and worse short and long-term outcomes in patients with acute myocardial infarction.^[26] Rassameehiran *et al.*^[22] demonstrated that the SI might be a useful tool for identifying patients with acute upper gastrointestinal bleeding (UGIB) who may have adverse short-term outcomes. It was comparable to other risk-scoring tools for UGIB and may have potential use as a risk stratification tool in UGIB. Balhara *et al.*^[24] determined that an elevated (>1.2) might predict hospital admission and in-patient mortality when used in the ER as a triage tool. Finally, Tseng and Nugent did an extensive literature review of SI in patients with sepsis and found that an elevated SI is useful in the evaluation of fluid resuscitation and in the identification of patients with lactic acidosis and organ failure increased mortality.^[23]

Several authors have compared the performance of SI versus MSI and ASI to identify the most convenient tool to estimate hemodynamic instability and the prognosis of the patients. Liu *et al.*^[17] found that MSI performed better than either SI or HR and blood pressure alone in predicting mortality in emergency patients. Torabi *et al.*^[27] compared SI, MSI, and ASI for the prediction of mortality in emergency patients and found that ASI performed better than SI and MSI. This study has shown that, in clinical emergencies that occur in emergency departments, simple bedside tools aid in the timely diagnosis and assessment of the patients. SI with better sensitivity and specificity can be utilized to assess the need for mechanical ventilation among sepsis patients admitted to the ER.

Limitations

The limitation of the current study is that ASI, SI, and MSI were calculated at the time of admission, and follow-up values were assessed only after 24 h and not throughout hospitalization. Hence, the predictive validity of the scores in later periods was not assessed.

CONCLUSION

In the current study, SI had better sensitivity and specificity compared to ASI and MSI in predicting the need for mechanical ventilation in sepsis patients admitted to ICUs. Hence, the use of such indices can aid in the timely diagnosis and appropriate treatment.

Research quality and ethics statement

This study was approved by the Institutional Review Board/Ethics Committee (The institutional ethical committee of Sri Devaraj Urs Medical College # SDUMC/KLR/IEC/277/2019-20). The authors followed EQUATOR Network (<https://www.equator-network.org/>) guidelines during the conduct of this research project.

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Conflicts of interest

There are no conflicts of interest.

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