Complementary value of the Shock Index v. the Modified Shock Index in the prediction of in-hospital intensive care unit admission and mortality: A single-centre experience

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Background. Shock is a state of circulatory insufficiency that creates an imbalance between tissue oxygen supply and demand, resulting in end-organ dysfunction and hypodynamic circulatory failure. Most patients with infectious and trauma-related illnesses present to the emergency department (ED) in shock.
Objectives. To study the usefulness of the shock index (SI) and modified shock index (MSI) in identifying and triaging patients in shock presenting to the ED.
Methods. This was a year-long observational, cross-sectional study of 290 patients presenting to the ED of a tertiary hospital in compensated or overt shock. The SI and MSI were calculated at the time of first contact, and then hourly for the initial 3 hours. Relevant background investigations targeting the cause of shock and prognostic markers were done. The outcome measures of mortality and intensive care unit admission were documented for each participant.
Results. The mean age of the participants was 49 years, and 67% of them were men. In consensus with local and national data, the major medical comorbidities were hypertension (20%) and diabetes mellitus (16%). An SI ≥0.9 and an MSI ≥1.3 predicted in-hospital mortality ($p<0.05$) and ICU admission ($p<0.05$) with no significant superiority of the MSI over the SI in terms of mortality, although the MSI was a better surrogate marker for critical care admission.
Conclusion. The study showed the complementary value of the SI and MSI in triage in a busy tertiary hospital ED, surpassing their components such as blood pressure, heart rate and pulse pressure. We determined useful cut-offs for these tools for early risk assessment in the ED, and larger multicentre studies are needed to support our findings.
Keywords. Shock, shock index, modified shock index, triage.

Afr J Thoracic Crit Care Med 2023;29(2):e286. https://doi.org/10.7196/AJTCCM.2023.v29i2.286

Study synopsis
What the study adds. The study highlights the usefulness of clinical bedside tools such as the shock index (SI) and modified shock index (MSI) in triaging patients in the emergency department, and their role in predicting morbidity and mortality.
Implications of the findings. Compared with systolic blood pressure, diastolic blood pressure and mean arterial pressure, alone or in combination, the SI and MSI had higher sensitivity and specificity in terms of outcome prediction. While both an elevated SI and an elevated MSI predicted in-hospital mortality, the MSI was a better surrogate marker for ICU admission.

Haemodynamic instability is a common finding in patients presenting to the emergency department (ED) of any healthcare facility. Appropriate triaging and timely intervention based on the severity of the patient's condition are beneficial to the patient and enable efficient use of resources. Shock is a state of circulatory insufficiency that creates an imbalance between tissue oxygen supply and demand, resulting in end-organ dysfunction.[1] Pathophysiologically, shock can be classified as distributive (33 - 50%), hypovolaemic (31 - 36%), cardiogenic (14 - 29%) or obstructive (1%). The major regulators of blood pressure are baroreceptors, which are further controlled by the sympathetic and vagal activity of the medulla. Other factors affecting blood pressure and heart rate are chemoreceptors and the renin-angiotensin-aldosterone system.[2]

The shock index (SI) provides information on the patient's haemodynamic status and is calculated as the ratio of heart rate (HR) to systolic blood pressure (SBP). It appears to be a reliable predictor of early shock in situations such as trauma, infection and pulmonary embolism, in which 0.9 is usually considered the threshold for comprehensive evaluation. It is considered sensitive in reflecting the pre-shock state, as tachycardia precedes hypotension in early/compensated shock states. A considerable amount of research has shown that a high SI predicts poor outcomes in terms of mortality after trauma. The SI is increasingly used to predict the duration and outcome of critical care admission, including patients on mechanical ventilation. In contrast, blood pressure (BP) or HR on their own are not as sensitive in predicting the severity of haemodynamic compromise.[3,4]

The modified shock index (MSI) is calculated as the ratio of HR to mean arterial pressure (MAP), which is the sum of diastolic blood pressure (DBP) and one-third of pulse pressure. The MSI indicates the diastolic rather than the systolic function of the heart and is therefore a near-ideal surrogate marker for cardiac compromise, as coronary perfusion is reliant on the diastolic function/duration. A high MSI can therefore be regarded as an ominous sign of low cardiac output and systemic vascular resistance, culminating in hypodynamic circulation.[5,6]

Although research has proved the sensitivity of the SI and MSI in investigating hypodynamic states, their actual predictive capability in terms of in-hospital mortality and duration of ICU admission in patients from the ED is not as well known.

Methods

This was a year-long observational, cross-sectional study of 290 patients who presented to the ED of a tertiary hospital in compensated or overt shock. All adult patients aged >18 years with predetermined threshold values for vital signs (BP <90/60 mmHg, MAP <65 mmHg, capillary refilling time >3 seconds, or other signs of haemodynamic collapse) were enrolled after written informed consent had been obtained from the patient or an accompanying family member. Any adult patient with decompensated shock due to any underlying cause, including but not limited to trauma or sepsis, was included. Patients who were on heart rate-regulating drugs or had atrioventricular block, cardiac arrhythmia, spinal cord injury or cardiorespiratory arrest, those who had received initial care out of the hospital, and those with incomplete data were excluded from the study. The parameters that were necessary for calculation of the SI and MSI were recorded at presentation and on an hourly basis for the initial 3 hours of hospitalisation. To obtain figures that could be analysed, we determined threshold values for the SI as 0.5 - 0.9 and those for the MSI as 0.7 - 1.3, in accordance with the findings of earlier research.[7] Any value over the cut-off limit at early monitoring was recorded for evaluation. The primary objective of the study was to measure in-hospital mortality in patients with a raised index, while the secondary objective was to determine the rate of ICU admission. The details were recorded on standard case record forms, and all data were entered into an Excel 2019 spreadsheet (Microsoft Inc., USA). Statistical analysis was done using Stata software, version 17, 2021 (StataCorp Inc., USA) The χ^2 test was used to calculate the p-value, with $p<0.05$ indicating significance.

Appropriate approval was received from the institutional ethics committee of the hospital before the initiation of the study (ref. no. BJMC/152/19).

Results

The mean age of the participants was 49 years, and 67% of them were men. In consensus with local and national data, the major medical comorbidities were hypertension (20%) and diabetes mellitus (16%). Sepsis and acute cardiac failure (decompensated) were the most common final diagnoses, and were invariably associated with increased mortality (Fig. 1).

Among the non-traumatic surgical emergencies, hollow viscus perforation (31%) and acute pancreatitis (17%) were frequent. A notable finding was that with an increase in the SI from 0.9 to 1.8, mortality rates showed a considerable increase from 19% to 90% (χ^2=57.0095 ($p<0.05$)) (1).

As with the SI, an MSI >1.7 was associated with an increased mortality rate, as shown in Table 2 (χ^2=67.813 ($p<0.05$)).

The sensitivity and specificity of the SI in predicting mortality were almost 100% and 23%, respectively (Table 3). An MSI of 1.5 - 2.1 was highly suggestive of relatively higher rates of ICU admission ($p<0.05$). As shown in Table 4, the sensitivity of the MSI in predicting mortality was 98% with a specificity of 23%, while the negative predictive value was 98%.

On analysis of individual parameters, an MAP <65 mmHg was found to be a predictor of mortality, with a sensitivity of 27% and a specificity of 97%. A DBP <60 mmHg was also statistically significant in predicting mortality, with a sensitivity of 75% and a specificity of 66%.

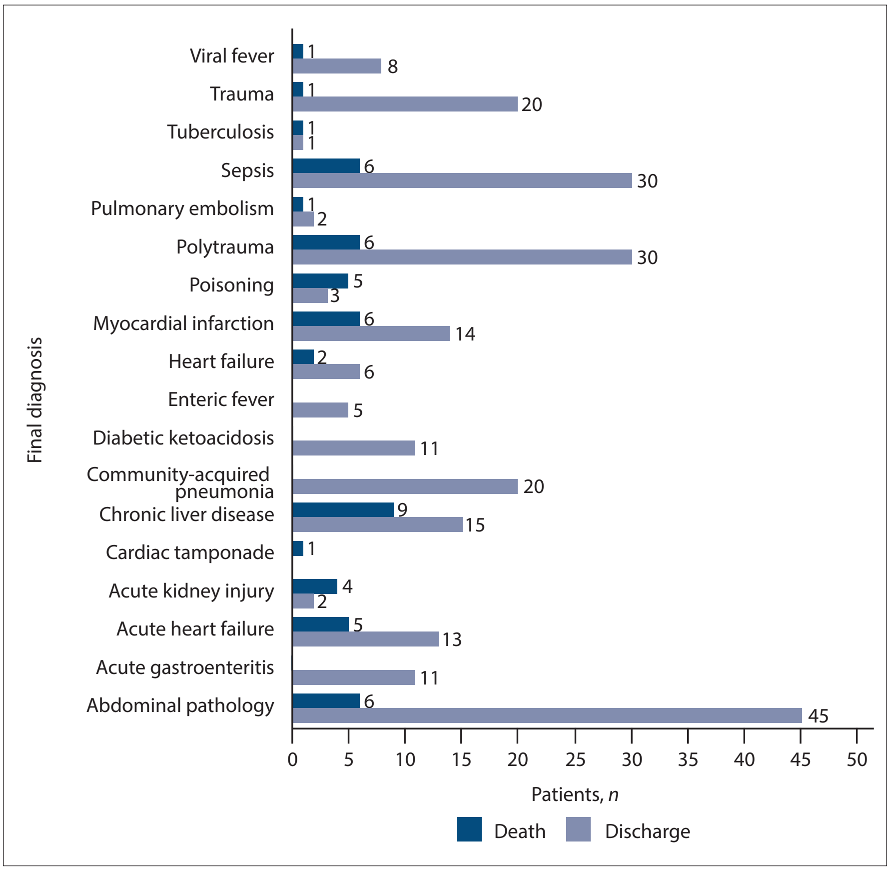

Fig. 1. Mortality in relation to final diagnoses.

Table 1. SI distribution and mortality

SI	Discharge, *n* (%)*	Death, *n* (%)*	Total, *n* (%)*
<0.9	5 (2.1)	0	5 (1.7)
0.9 - 1.1	152 (64.4)	10 (18.5)	162 (55.8)
1.2 - 1.4	68 (28.8)	28 (51.8)	96 (33.1)
1.5 - 1.7	10 (4.2)	11 (20.3)	21 (7.2)
1.8 - 2.0	1 (2.1)	4 (7.4)	5 (1.7)
≥2.1	0	1 (1.8)	1 (0.3)
Total, N	236	54	290

SI = shock index.
*Except where otherwise indicated.

Table 2. MSI distribution and mortality

MSI	Discharge, *n* (%)*	Death, *n* (%)*	Total, *n* (%)*
<1.1	1 (0.4)	0	1 (0.3)
1.1 - 1.2	62 (26.2)	1 (1.8)	63 (21.7)
1.3 - 1.4	63 (26.6)	6 (10.7)	69 (23.7)
1.5 - 1.6	56 (23.7)	8 (14.2)	64 (22.1)
1.7 - 1.8	29 (12.2)	17 (30.3)	46 (15.8)
1.9 - 2.0	16 (6.7)	9 (16.7)	25 (8.6)
2.1 - 2.2	8 (3.3)	6 (10.7)	14 (4.8)
≥2.3	1 (0.4)	7 (12.5)	8 (2.7)
Total	236	54	290

MSI = modified shock index.
*Except where otherwise indicated.

Table 3. Sensitivity and specificity of the SI

SI	Death, *n*	Discharge, *n*	Total, *N*
≥0.9	54	231	285
<0.9	0	5	5
Total	54	236	290
Sensitivity, %	Specificity, %	PPV, %	NPV, %
100	23	19	100

SI = shock index; PPV = positive predictive value; NPV = negative predictive value.

Table 4. Sensitivity and specificity of the MSI

MSI	Death, *n*	Discharge, *n*	Total, *N*
≥1.3	53	173	226
<1.3	1	63	64
Total	54	236	290
Sensitivity, %	Specificity, %	PPV, %	NPV, %
98	23	23	98

MSI = modified shock index; PPV = positive predictive value; NPV = negative predictive value.

Table 5. Comparison of the SI and MSI for prediction of mortality

	Death, *n*	Discharge, *n*	Total, *N*	Significance
MSI ≥1.3	53	173	226	$\chi 2=1.544$
SI ≥0.9	54	231	285	(p=0.213)
Total	107	404	511	

SI = shock index; MSI = modified shock index.

Table 6. Comparison of the SI and MSI for prediction of ICU admission

	ICU admission, *n*	Ward admission, *n*	Total, *N*	Significance
MSI ≥1.3	142	84	226	χ2 = 8.185
SI ≥0.9	143	142	285	(p = 0.004)
Total	285	226	511	

SI = shock index; MSI = modified shock index; ICU = intensive care unit.

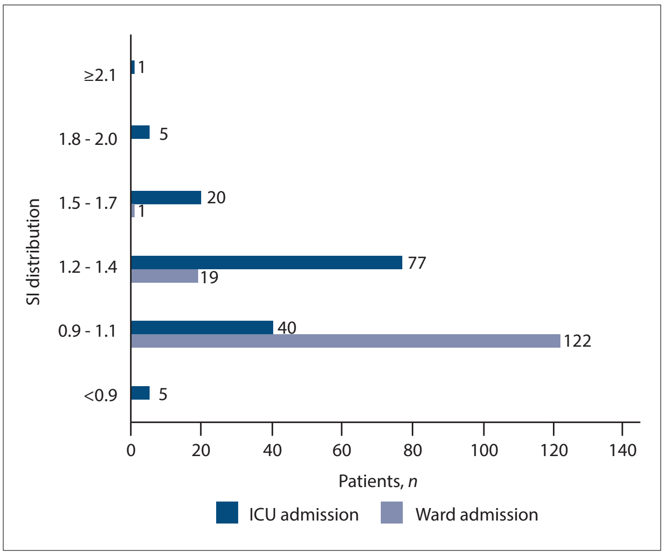

Fig. 2. SI and ICU admission. (SI = shock index; ICU = intensive care unit.)

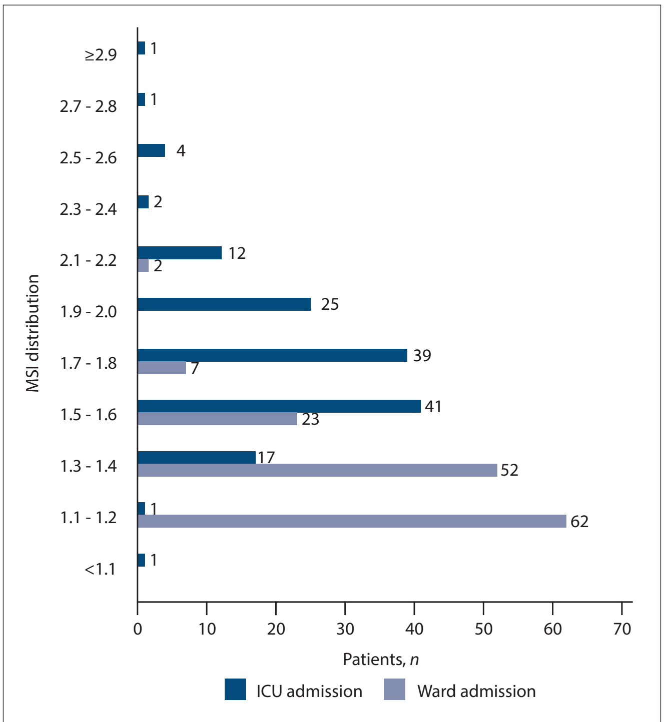

Fig. 3. MSI and ICU admission. (MSI = modified shock index; ICU = intensive care unit.)

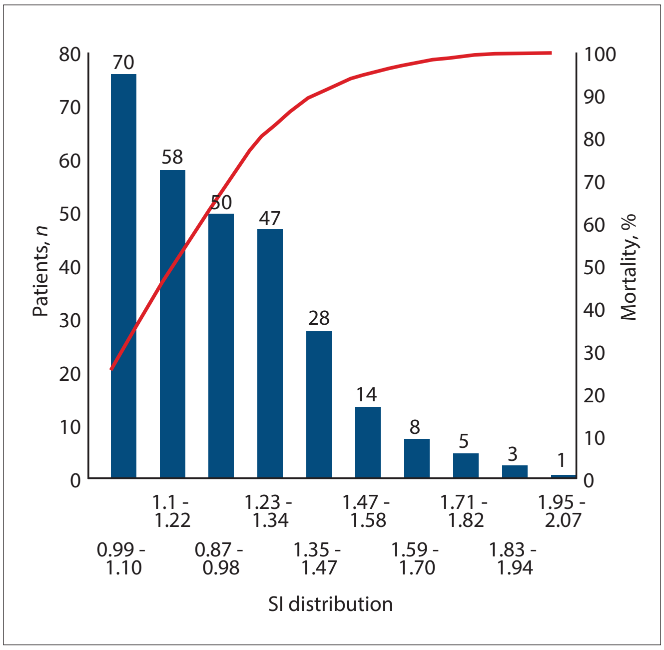

Fig. 4. SI mortality trend (red curve). (SI = shock index.)

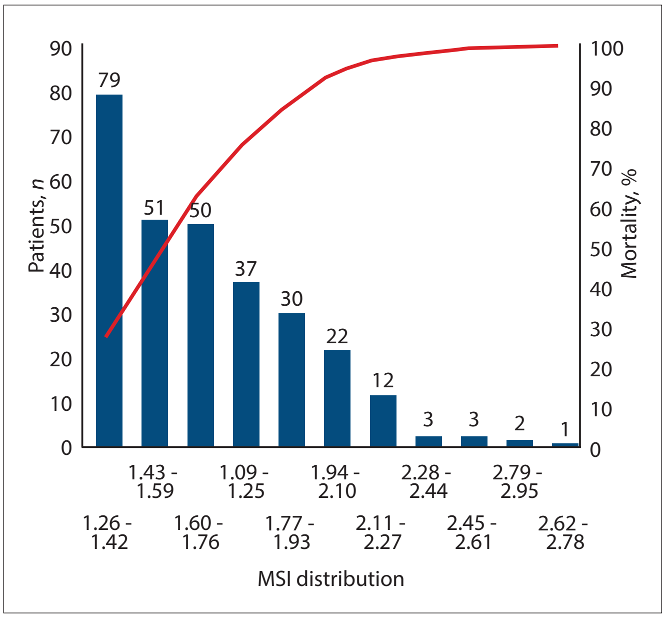

Fig. 5. MSI mortality trend (red curve). (MSI = modified shock index.)

In a head-to-head comparison of the SI and MSI, it was firmly established that the MSI is not better than the SI in terms of predicting mortality, although the MSI was more useful in predicting ICU admission from the ED (Tables 5 and 6).

Discussion

The SI was first proposed in the 1960s to identify apparently stable yet critically ill trauma patients in the ED. It has since been shown to be a simple, non-invasive risk stratification tool useful for detecting changes in cardiovascular performance before the onset of systemic hypotension and cardiorespiratory collapse, especially in patients with cardiogenic shock, sepsis, ectopic pregnancy, gastrointestinal haemorrhage and acute pulmonary embolism.[8] In the present study, in consensus with previous research on 2 500 patients by Berger *et al*.,[9] an SA ≥0.9 at presentation had a clinically significant association with in-hospital mortality. Berger *et al*.[9] found that an SI >1 was the most specific predictor of both hyperlactataemia and 28-day mortality in their study, while a score of ≥0.85 predicted ICU admission in a retrospective analysis at a single centre by Keller *et al*.[10] Analogous application of the SI in patients with acute coronary syndrome and community-acquired pneumonia proved beneficial in other studies.[11,12] An MSI ≥1.3 predicted mortality with a high sensitivity of 98% and a specificity of 23%, and a logarithmic increase in MSI was associated with increased mortality. The same cut-off of 1.3 was found to be convincingly useful in studies of patients with non-cause-specific reasons for shock.[5,13]

With sensitivity analysis (Figs 2 - 5), an SI ≥0.9 and an MSI ≥1.3 at initial assessment in the ED predicted in-hospital mortality and ICU admission rates with no significant superiority of the MSI over the SI in terms of mortality, although the MSI was a better surrogate marker for critical care admission.

There were certain limitations to our study, such as the relatively small sample size and lack of a uniform definition of an abnormal SI, which was given in the range of 0.7 - 1.0. The study was done in only one centre, and to extrapolate the findings to a general population, multicentre studies may be necessary.

Conclusion

The study showed that an SI ≥0.9 and an MSI ≥1.3 at first ED contact predict in-hospital mortality and ICU admission. As shock indices can be measured at the bedside, they are useful in predicting a patient's clinical course and survival probability. Further larger and multicentre studies are needed to support our findings and shed more light into the tunnel of ED triaging of sick patients, especially in resource-limited countries.

Declaration. The research for this study was done in partial fulfilment of the requirements for SS's MD (Emerg Med) degree at Gujarat University, India.

Acknowledgements. We thank the faculty and staff of the Department of Emergency Medicine, B J Medical College and Civil Hospital, Ahmedabad, for assisting with the study.

Author contributions. SS: conceptualised the study, drafted the protocol and collected the data. SJ: performed the statistical analysis and wrote the manuscript. ABJ: assisted with protocol development and reviewed the manuscript. All authors approved the final document for publication.

Funding. None.

Conflicts of interest. None.

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Submitted 12 September 2022. Accepted 3 May 2023. Published July 2023.