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Research Paper

Predictive value of the Shock Index for in-hospital mortality and blood transfusion in trauma patients: A retrospective study

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ABSTRACT

The Shock Index (SI), defined as heart rate divided by systolic blood pressure, is a simple bedside marker of hemodynamic instability in trauma. However, its predictive value for primary clinical outcomes remains debated. This retrospective cohort study evaluated the ability of SI measured at emergency department admission to predict in-hospital mortality and the need for blood transfusion among adult trauma patients triaged as Level I or II at a single trauma center between 2021 and 2022. A total of 185 patients were included (mean age 62.2 ± 22.3 years; 36.8% female). In-hospital mortality occurred in 78 patients (42.2%), and 44 (23.8%) required transfusion. Overall, SI demonstrated limited discriminative performance for mortality (Area Under the Curve (AUC) = 0.574; 95% Confidence Interval (CI): 0.49–0.66; p = 0.088) and transfusion (AUC = 0.573; 95% CI: 0.49–0.66; p = 0.135). Optimal cutoffs showed modest sensitivity but poor specificity. In exploratory subgroup analyses with small sample sizes, higher discrimination was observed in select groups, including patients with Glasgow Coma Scale (GCS) 13–15 (AUC = 0.768); however, these findings should be interpreted cautiously. Multivariable Cox regression identified higher Injury Severity Score, lower Glasgow Coma Scale, and need for mechanical ventilation as independent predictors of mortality, whereas SI was not independently associated with survival. In this single-center cohort, SI showed limited overall utility as a standalone predictor of mortality or transfusion, and its potential role may be restricted to specific clinical contexts requiring further validation.

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1. Introduction

Trauma and the injuries it causes represent significant health, economic, and social challenges worldwide, particularly in the first four decades of life [1]. The mechanisms of trauma can expose patients to various risks, with complications closely tied to the type of injury sustained. Additionally, improper or delayed resuscitation can lead to fluid imbalances and respiratory issues, further complicating the patient's condition [2]. Hemorrhagic shock is a leading cause of trauma-related death, accounting for approximately 40% of these cases, making it a critical and preventable factor. Effective management of trauma-induced shock requires a comprehensive approach, including protocols for severe bleeding, targeted resuscitation, hypothermia control, electrolyte management, damage control surgery, and the use of pharmacological treatments such as anticoagulants [3]. Although vital signs and clinical assessments are commonly used to diagnose shock in trauma patients, they are not always reliable indicators of the patient's actual physiological state. For example, responses to hemorrhage, such as hypotension and tachycardia, do not always align with the severity of the shock, leading to the potential underestimation of a patient's condition [3]. This gap highlights the need for more reliable markers, such as the SI (Shock Index), to assess the severity of shock in trauma settings. Introduced in 1967, the SI is calculated as the heart rate-to-systolic blood pressure ratio and provides a rapid, noninvasive method for evaluating hypovolemia in patients with hemorrhagic shock [4]. Over time, the SI has emerged as a more sensitive predictor than vital signs alone [5], particularly in cases of circulatory failure where traditional metrics may fail to reflect the severity of the condition [6]. The utility of the SI extends beyond the hospital setting; it is also valuable in prehospital environments [7], where early detection of hemorrhagic shock is critical and has been associated with increased likelihood of hospital admission and mortality in select prehospital cohorts. Moreover, since the likelihood of hospitalization and mortality increases, especially at an SI threshold of >1.2, it becomes a vital tool for guiding immediate treatment decisions [8]. However, while the SI has been validated in numerous studies, its predictive power is not uniform across all patient populations [9]. In particular, its effectiveness can diminish in elderly patients [10], and its accuracy may be affected by comorbidities such as coronary artery disease, diabetes, and hypertension [11].

This study aims to evaluate the SI's ability to predict in-hospital mortality and the need for blood transfusion in trauma patients. By analyzing a cohort of patients with diverse injury mechanisms and clinical characteristics, we seek to provide insights into the utility of the SI in trauma care and highlight its potential limitations. Ultimately, our findings aim to contribute to the growing body of literature on trauma assessment tools and enhance the quality of care for critically injured individuals.

2. Materials and Methods

2.1 *Study Design and Setting*

This retrospective cohort study used data from the institutional trauma registry of Poursina Hospital, a Level II trauma center affiliated with Guilan University of Medical Sciences in Rasht, Iran. All eligible trauma admissions between January 2021 and December 2022 were screened. The study was designed to evaluate the prognostic performance of the Shock Index (SI) measured at emergency department (ED) admission for predicting in-hospital mortality and the need for blood transfusion.

2.2 *Study Population*

Adult patients (≥18 years) triaged as Level I or II trauma activations were eligible for inclusion. These levels correspond to patients with hemodynamic instability, high-risk mechanisms of injury, or severe clinical presentations requiring immediate trauma team activation. Patients were excluded if they had isolated head injuries or isolated extremity injuries, as these conditions follow distinct pathophysiological trajectories and management strategies that could confound the relationship between SI and outcomes. Additional exclusions included transfer from another facility, direct admission to the intensive care unit without ED evaluation, an injury-to-admission interval greater than 24 hours, death in the ED, or incomplete medical records. These criteria were applied to ensure uniformity in initial physiological assessment and outcome ascertainment. Eligible patients were enrolled using consecutive sampling based on registry availability.

2.3 *Data Collection and Variables*

Demographic data, injury characteristics, comorbidities, admission vital signs, Glasgow Coma Scale (GCS), Injury Severity Score (ISS), need for mechanical ventilation, procedural interventions, blood transfusion, and in-hospital mortality were extracted from the trauma registry. The Shock Index was calculated as heart rate divided by systolic blood pressure using the first recorded ED values.

2.4 *Statistical Analysis*

Statistical analyses were performed using SPSS version 25.0 (IBM Corp., Armonk, NY). Continuous variables were summarized as mean ± SD or median (IQR), depending on the Shapiro–Wilk test, and categorical variables as frequencies and percentages. Group comparisons used Student’s t-test or Mann–Whitney U test for continuous variables and chi-square or Fisher’s exact test for categorical variables. The predictive performance of the Shock Index (SI) for in-hospital mortality and blood transfusion was assessed using Receiver Operating Characteristic (ROC) curve analysis, with AUC and 95% CI calculated. Youden’s

index determined optimal cutoffs. Exploratory subgroup ROC analyses were performed by sex, underlying disease, GCS, and ISS. Time-to-event analysis for mortality was conducted using Kaplan–Meier curves and log-rank tests. Multivariable Cox regression identified independent predictors of mortality; proportional hazards were verified using Schoenfeld residuals. Missing data (<5%) for heart rate and systolic blood pressure were handled by single stochastic regression imputation, with sensitivity analyses confirming similar results.

3. Results

3.1 *Study Cohort Characteristics*

A total of 185 patients met the inclusion criteria and were included in the analysis. The mean age was 62.2 ± 22.3 years, and 36.8% were female. Traffic accidents and falls accounted for the majority of injuries. Two-thirds of patients had at least one underlying comorbidity. The mean ISS was 19.1 ± 9.8, and the mean admission Shock Index was 0.60 ± 0.20. Overall, in-hospital mortality was 42.2%, and 23.8% of patients required blood transfusion (Table 1).

3.2 *Overall Predictive Performance of Shock Index*

The Shock Index demonstrated limited discriminative ability for predicting in-hospital mortality (AUC = 0.574, 95% CI: 0.49–0.66; p = 0.088) and blood transfusion (AUC = 0.573, 95% CI: 0.49–0.66; p = 0.135). Optimal cut-off values were associated with modest sensitivity but poor specificity (Figure 1 and 2).

3.3 *Exploratory Subgroup Analyses*

In exploratory analyses, higher AUC values were observed in select subgroups. Notably, among patients with GCS 13–15, SI showed improved discrimination for mortality (AUC = 0.768).

Moderate performance was also observed in patients with underlying disease. Given the limited sample sizes and absence of adjustment for multiple comparisons, these findings should be interpreted cautiously and considered hypothesis-generating (Table 2 and 3).

3.4 *Predictors of In-Hospital Mortality*

In multivariable Cox regression analysis, lower GCS, higher ISS, and the need for mechanical ventilation were independently associated with increased mortality. Each one-point decrease in GCS was associated with a 24% increase in the hazard of death. Compared with patients with ISS <15, those with ISS >25 had a significantly higher risk of mortality.

Shock Index was not independently associated with survival after adjustment for injury severity and clinical variables (Table 4).

Table 1. Baseline demographic and clinical characteristics of the study population (n = 185).

Variable	Value
Age, years	62.2 ± 22.3
Sex, n (%)	
Male	117 (63.2)
Female	68 (36.8)
Underlying disease, n (%)	123 (66.5)
Mechanism of injury, n (%)	
Traffic accident	97 (52.4)
Fall	55 (29.7)
Assault (penetrating/blunt)	25 (13.5)
Other	8 (4.3)
Injury Severity Score (ISS)	19.1 ± 9.8
Shock Index at admission	0.60 ± 0.20
Mechanical ventilation, n (%)	129 (69.7)
Chest tube/CVP/Tracheostomy (any), n (%)	49 (26.5)
In-hospital mortality, n (%)	78 (42.2)
Blood transfusion, n (%)	44 (23.8)

ISS: Injury Severity Score; CVP: Central Venous Pressure monitoring. Continuous variables are presented as mean ± standard deviation; categorical variables are presented as number (percentage).

Table 2. Shock Index cutoff determination for predicting in-hospital mortality.

Variable	Subcategory	n	Cutoff	Sensitivity (%)	Specificity (%)	AUC	P value
Gender	Male	117	0.630	55.3	62.9	0.571	0.202
	Female	68	0.724	29.0	89.2	0.580	0.263
Underlying disease	Yes	123	0.601	62.9	63.9	0.626	0.013
	No	62	0.724	93.8	19.6	0.518	0.827
GCS	≤8	61	0.410	98.0	27.3	0.590	0.414
	9–12	66	0.625	61.5	62.5	0.618	0.117
	13–15	58	0.637	100.0	67.9	0.768	0.008
ISS	<15	80	0.579	87.5	47.2	0.656	0.045
	15–25	26	0.567	62.5	72.2	0.618	0.416
	>25	79	0.639	45.2	76.5	0.553	0.447

Table 3. Shock Index cutoff determination for predicting blood transfusion.

Variable	Subcategory	n	Cutoff	Sensitivity (%)	Specificity (%)	AUC	P value
Gender	Male	117	0.565	79.3	37.5	0.557	0.358
	Female	68	0.595	73.3	56.6	0.604	0.214
Underlying disease	Yes	123	0.595	68.8	55.0	0.557	0.321
	No	62	0.683	50.0	80.0	0.623	0.043
GCS	≤8	61	0.572	85.7	42.6	0.629	0.002
	9–12	66	0.724	100.0	20.4	0.533	0.684
	13–15	58	0.522	100.0	31.1	0.638	0.107
ISS	<15	80	0.615	64.3	57.6	0.545	0.602
	15–25	26	0.521	100.0	38.1	0.505	0.505
	>25	79	0.559	88.0	29.6	0.551	0.470

Table 4. Multivariable Cox proportional hazards model for in-hospital mortality.

Variable	Category	HR (95% CI)	P value
Glasgow Coma Scale (per 1-point decrease)	—	1.24 (1.14–1.35)	<0.001
Injury Severity Score (ISS)	<15	Reference	—
	15–25	2.12 (0.81–5.54)	0.126
	>25	3.55 (1.71–7.37)	0.001
Mechanical ventilation	Yes, vs No	5.02 (1.15–21.69)	0.032

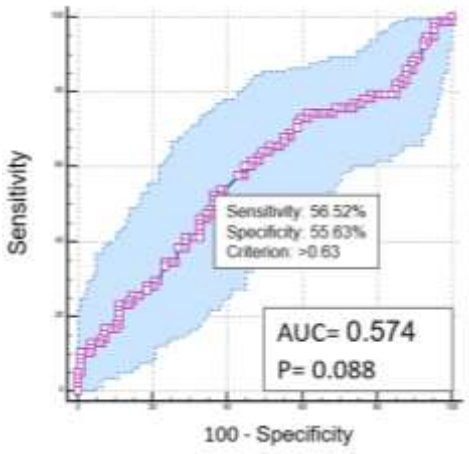

Figure 1. ROC curve for SI and mortality.

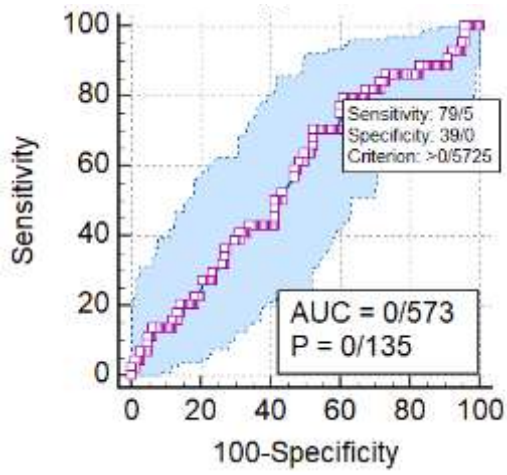

Figure 2. ROC curve for SI and the need for blood transfusion.

4. Discussion

This study evaluated the Shock Index (SI) as a predictor of in-hospital mortality and the need for blood transfusion in trauma patients. Trauma remains a leading cause of death and disability worldwide, with outcomes largely dependent on injury severity and the timeliness and quality of medical care [12]. Given the heterogeneity of trauma patients, early and reliable prognostic indicators are essential for triage, resource allocation, and clinical decision-making [13].

In our cohort, SI showed limited discriminative ability for predicting mortality (AUC = 0.574) and blood transfusion (AUC = 0.573), both below the threshold generally considered clinically acceptable (AUC ≥ 0.70). This finding is consistent with a recent 2023 meta-analysis reporting that SI alone has limited accuracy in predicting mortality among trauma patients [14]. The modest performance observed in our study may be explained by the heterogeneity of the population, including variations in injury mechanisms, comorbidities, and prehospital or early in-hospital management, which could attenuate the predictive value of a single physiologic index [15]. Additionally, unmeasured factors, such as the timing of resuscitation, analgesia, or prehospital interventions, may have influenced admission vital signs and, consequently, SI values.

Regarding blood transfusion, our results did not support SI as a strong standalone predictor. This contrasts with previous studies suggesting that higher SI values are associated with increased transfusion requirements, including reports that SI thresholds of 0.91 and 1.14 significantly increase transfusion risk [16], and findings indicating that SI >1 may be more sensitive than the Assessment of Blood Consumption (ABC) score for predicting massive transfusion, albeit with lower specificity [17]. These discrepancies suggest that SI may be more useful in selected populations or when combined with other clinical parameters rather than used in isolation.

Underlying comorbidities influence the predictive performance of SI. Prior studies indicate that SI performs better in patients without chronic diseases. In contrast, its accuracy may be reduced in individuals with hypertension, diabetes, or coronary artery disease due to

altered hemodynamic responses [18]. Baseline hypertension and medications such as beta-blockers or calcium channel blockers can blunt tachycardic responses to hypovolemia, thereby diminishing the sensitivity of SI [19,20]. This likely contributed to the limited overall performance observed in our cohort, where two-thirds of patients had at least one underlying disease.

Consistent with previous literature, GCS and ISS were strong independent predictors of mortality in our study [21,22]. Patients with ISS >25 had a significantly higher risk of death, aligning with large-scale studies demonstrating a clear relationship between increasing ISS and mortality [23]. Furthermore, the need for mechanical ventilation was associated with a fivefold increase in mortality, reflecting its role as a marker of severe injury and physiological compromise rather than a direct causal factor. Although procedural interventions such as chest tube placement or invasive monitoring are essential components of trauma care and are associated with improved outcomes in specialized centers [24], the inverse association observed in our cohort likely reflects survival bias and confounding by indication. Critically unstable patients may have died before receiving definitive procedures, creating an apparent but non-causal protective association.

Overall, our findings support a multimodal approach to trauma risk stratification rather than reliance on a single vital sign ratio. While SI may be useful in specific clinical contexts or subgroups, it should be interpreted alongside established predictors, such as GCS, ISS, and other clinical indicators.

Several limitations should be acknowledged. The single-center design and relatively small sample size may limit generalizability. The exclusion of patients who died in the emergency department or were directly admitted to the ICU may have underestimated the actual predictive value of SI in the most severely injured patients. Additionally, no a priori sample size or power calculation for ROC analysis was performed, which may affect the interpretation of negative findings. Future multicenter studies with larger sample sizes and integrated predictive models are warranted better to define the role of SI in trauma prognosis.

In this single-center trauma cohort, the Shock Index demonstrated limited overall utility as a standalone predictor of in-hospital mortality or blood transfusion. While exploratory subgroup analyses suggested improved performance in select clinical contexts, these findings require prospective validation. Comprehensive trauma risk stratification should rely on integrated models (ISS, GCS, and clinical indicators) rather than isolated vital sign ratios.

Authors' contributions

SR: Conceptualization, study design, supervision, critical revision, final approval. SMZZ: Study design, statistical oversight, critical revision, final approval. MP: Data collection, original draft, table/figure preparation. RS: Data collection, registry coordination, quality control. ASN: Statistical analysis (SPSS), ROC/Cox modeling, interpretation. NNR: Data interpretation, manuscript revision (critical), final approval. All authors read and approved the final version of the manuscript.

Conflict of interest

No potential conflict of interest was reported by the authors.

Ethical declarations

The study was approved by the Ethics Committee of Guilan University of Medical Sciences (IR.GUMS.REC.1402.030). All data were anonymized prior to analysis.

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