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PREDICTIVE ACCURACY OF SHOCK INDEX VERSUS MODIFIED SHOCK INDEX IN IDENTIFYING SEVERE HEMORRHAGE IN EMERGENCY TRAUMA PATIENTS

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Abstract

Severe hemorrhage is a leading cause of preventable early mortality in trauma patients, and rapid identification of those at high risk is essential for timely intervention. Traditional vital signs often fail to detect early circulatory compromise, prompting the use of composite hemodynamic indices such as the Shock Index (SI) and Modified Shock Index (MSI). This study aimed to compare the predictive accuracy of SI and MSI in identifying severe hemorrhage among adult trauma patients presenting to a tertiary-care emergency department. A prospective cross-sectional design was employed, enrolling 240 adult trauma patients aged 18–65 years. Heart rate, systolic and diastolic blood pressure, and mean arterial pressure were recorded at presentation before resuscitation. SI and MSI were calculated, and severe hemorrhage were diagnosed using clinical assessment, transfusion requirements, and need for emergent hemostatic intervention. Diagnostic accuracy was assessed through sensitivity, specificity, predictive values, overall accuracy, and ROC-curve analysis. Severe hemorrhage was identified in 36.2% of patients. Both indices were significantly higher among hemorrhagic patients (SI: 1.33 vs. 0.94; MSI: 1.82 vs. 1.36; $p < 0.001$). MSI demonstrated superior diagnostic performance with higher sensitivity (86.2%), specificity (79.7%), and overall accuracy (82.5%) compared to SI. ROC analysis showed AUC values of 0.89 for MSI and 0.81 for SI, indicating better discriminative ability for MSI. Subgroup analysis further revealed consistently stronger performance of MSI across both blunt and penetrating trauma. MSI outperformed SI in predicting severe hemorrhage at emergency department arrival, demonstrating higher sensitivity, specificity, and discriminative capability. MSI represents a more reliable early triage tool for hemorrhage identification and may improve timely activation of hemorrhage control pathways in trauma care

INTRODUCTION

Severe hemorrhage continues as one of the primary causes of early preventable death after injury globally, and quick identification of patients at risk for both ongoing and massive bleeding is a foundation in emergent trauma care. Conventional vital signs, including heart rate and systolic blood pressure, are frequently employed as at-the-bedside indicators of traumatic hemorrhage, but they may be late signals of hemodynamically significant blood loss; compensatory mechanisms may obscure hypovolemia until a large proportion of circulating blood volume has been lost (Jones et al., 2023). Through the prior two decades, there has been interest in the Shock Index (heart rate divided by systolic blood pressure) and its derivatives (such as Modified Shock Index (MSI): heart rate divided by mean arterial pressure) as a more sensitive early warning of hemodynamic compromise than individual vital signs alone. These easy-to-use, bedside ratios do not depend on sophisticated monitoring equipment, are reliable across providers and can be calculated from the earliest recorded prehospital or emergency department vital signs, a feature that makes them appealing candidates for use as triage tools and as triggers for hemorrhage management protocols (Sharma et al., 2019).

Notwithstanding this, who does better and what numeric thresholds should trigger activation of the massive transfusion protocols (MTP) or instigate immediate surgical/angiographic intervention for individual types of trauma remains elusive. The SI has been extensively described and tested with proposed cutoffs (for instance 0.9–1.0) associated to higher risk of massive transfusion, ICU admission, or death, while the MSI is an attempt of adding diastolic blood pressure to more accurately estimate organ perfusion/vessel tone through calculation of mean arterial pressure (Mogashane et al., 2025). Results from comparative studies have been inconsistent, with some noting that MSI outperformed SI when mortality or need-for-transfusion end points were considered and others finding no difference between the two indices (Rau et al., 2016). These discrepancies can probably be attributed to variance in the study design (retrospective vs. prospective), case mix (blunt vs. penetrating trauma, age distribution), timing of vital sign capture (prehospital vs ED), and outcome definition (massive transfusion [MT], Critical Administration Threshold [CAT], hemostatic intervention, or hemorrhage-related mortality) (Meyer et al., 2018). It is therefore clinically useful to differentiate the relative predictive accuracies of SI and MSI for severe hemorrhage (as opposed to combined endpoints) in trauma patients presenting acutely.

This study seeks to determine and prospectively compare the predictive ability of SI and MSI for severe blood loss across adult trauma patients (Ghosh, 2025). The definition of severe hemorrhage will use modern clinical endpoints in practice, activation of massive transfusion, a threshold transfusion requirement within 4 hours that is locally adopted to indicate critical administration of blood or the need for empiric measures to control hemorrhage, so that the results are operational in trauma care delivery. By examining diagnostic discrimination (AUC), sensitivity, specificity and clinically useful cutoffs, it aims to generate evidence to assist in Early Triage Decision Making (eTDM) and Haemorrhage Control Pathways (Pundkar et al., 2025). The primary hypothesis is MSI will have not less than non-inferior discrimination to SI for severe bleeding at presentation, with performance and optimal cut-off values differing between subgroups (e.g., blunt vs penetrating trauma; older age groups) such that stratified analysis is required.

Beyond perfect diagnostic accuracy, it is likely that clinical practice will also be constrained by other issues: that an index or score that modestly assuages early detection while being easy to compute and interpret could conceivably reduce the time to definitive control without inappropriate under-triage. Conversely, an index with a high false positive rate may result in blood overuse, unnecessary activation of resource-intensive protocols and an associated higher iatrogenic risk. Therefore, beyond comparison of AUCs, the study aims to derive optimum operating points (cutoff) which balance sensitivity and specificity in a manner sensitive to trauma system objectives

(Carrington et al., 2022). The evidences shall support the institutions guidance in respect to the decision on using SI, MSI or combined algorithm when regarding initial trauma assessment and massive transfusion triggers.

Review of Literature

Early research into basic hemodynamic ratios started with the simple observation that tachycardia and hypotension when combined as a single value result in earlier identification of decompensation than either vital sign alone. The SI (HR / SBP) has been described in the literature as a readily calculable bedside heuristic, and a number of studies in both civilian and military trauma populations have noted an association between higher SI and greater likelihood of massive transfusion, higher Injury Severity Scores (ISS) scores, ICU admissions, and mortality (Le et al., 2016). Central to the SI research is a concept that an incremental value above baseline (thresholds in frequently referenced ranges approximately 0.9–1) indicates that compensation has failed and the risk of significant bleeding is greater. Meta-analyses and narrative reviews have indicated that SI has moderate discriminating capabilities but that threshold performance is context-dependent, for example elderly patients may exhibit attenuated tachycardic responses, leading to lower sensitivity of SI unless age-adjusted indices are utilized. These underpinnings set the stage for several subsequent comparative trials (Aglen et al., 2025).

The Modified Shock Index (MSI) has been created as an effort to account for the contribution of diastolic pressure and effective coronary perfusion pressure. The formula: MSI = HR/MAP represents yet another calculated parameter that may potentially lend to identifying patients at risk secondary to hypotension. Theoretically, due to better reflection of organ perfusion pressure with MAP, especially under vasoconstricted conditions, MSI can detect hypoperfusion sooner or better compared to SI (Curcio et al., 2020). Empirical testing of MSI in traumatic and other acute care populations has yielded mixed results. Some retrospective series and registry studies found MSI to have AUCs quite similar or somewhat better than those for SI in predicting transfusion needs or 24-hour mortality; others did not find any significant superiority and, in some subpopulations of patients, no obvious benefit after controlling for age and mechanism of injury (Roy Beigel, 2018). Variability in endpoints (e.g., predicting massive transfusion protocol vs. within a fixed time frame prediction of operation) is another major source of heterogeneity among studies.

Several cohort studies focusing on prediction of massive transfusion or critical bleeding have reported for more specific performance measures. For instance, previous multicenter trauma investigation showed that SI had acceptable discriminative ability (AUCs were often reported in the 0.70–0.85 interval for transfusion outcomes) while MSI occasionally yielded AUCs in a matching range but not always achieving statistical superiority (Rau et al., 2016). In a large single-center series in which multiple shock indices were assessed, both SI and MSI correlated with transfusion requirements and mortality; however, their added benefit over standard triage tools was marginal, and performance differed by subgroups such as penetrating versus blunt trauma (Althunayyan et al., 2019). The explanation of these contradictory findings is that although both indices are potentially helpful adjuncts, neither is a fail-safe guide and added to other clinical information they contribute even less in itself.

Outside of trauma-focused populations, comparison between SI and MSI has also been investigated in haemorrhage (postpartum haemorrhage, surgical bleeding). For obstetric hemorrhage, single-center retrospective analyses demonstrated utility of both indices for predicting massive transfusion, with AUCs frequently >0.80; however, MSI was not uniformly superior to SI in those datasets (Rau et al., 2016). These trans-disciplinary findings suggest generalisability of the indices as hemorrhage-predictors while also highlighting that physiological context and patient-level characteristics at baseline (including pregnancy-associated cardiovascular changes) significantly affect diagnostic thresholds and operating performance. Extrapolating these results to trauma care highlights that patient specific calibration of cutoffs is probably required.

Several methodologic themes emerge from the literature that directly inform the design and interpretation of studies comparing SI and MSI. First, timing of measurement is crucial: prehospital vital signs, the first ED measurement, and serial measurements provide different predictive information and different operating points; early prehospital abnormality may allow intervention sooner but is subject to measurement variability (Schellenberg et al., 2020). Second, endpoint heterogeneity, whether the study defines severe hemorrhage by activation of a protocol, transfusion volume over a fixed interval, or requirement for operative/angiographic hemostasis, materially affects sensitivity/specificity estimates. Patient heterogeneity (age, comorbid cardiovascular disease, use of beta-blockers, mechanism of injury) can blunt expected physiologic responses, leading to lower sensitivity in certain subgroups; several authors therefore advocated stratified analyses or age-adjusted indices. Finally, although multiple large registries and single-center cohorts report statistical associations, few prospective interventional studies have tested whether using SI or MSI as part of an algorithm improves outcomes; thus, existing literature largely informs diagnostic accuracy rather than causally demonstrating clinical benefit (Rueschoff et al., 2021).

Most comparative analyses report AUC values and derive optimal cutoffs via Youden's index or similar methods; reported optimal thresholds vary (SI cutoffs of ~0.9–1.2; MSI thresholds reported in a wider range depending on MAP distributions), and corresponding sensitivity and specificity trade-offs are not universally consistent. Several recent large retrospective studies and registry analyses therefore call for context-specific validation and for trauma systems to consider the balance between under-triage (missed severe hemorrhage) and over-triage (false alarms, resource burden) when selecting thresholds (Bradfield, 2024). Moreover, literature reviews emphasize the potential value of combining shock indices with other rapid bedside information such as mechanism of injury, point of care hemoglobin, focused assessment with sonography for trauma (FAST) results, to enhance early identification of patients who will require definitive hemorrhage control. These recommendations highlight the likely practical end point of research: an evidence-based, context-tuned algorithm rather than a single universal numeric cutoff.

The extant literature supports the utility of SI and MSI as simple, early predictors of severe hemorrhage and transfusion need in trauma patients, but it does not definitively establish superiority of one index across all clinical contexts. Many studies demonstrate moderate discriminatory power for both indices, while heterogeneity in thresholds and endpoints undermines universal adoption of a single metric without local validation. The literature therefore justifies a focused, prospective comparison of SI and MSI for severe hemorrhage in emergency trauma patients with careful attention to measurement timing, clinically meaningful endpoints, and subgroup analyses, precisely the gaps this research will address.

Methodology

3.1 Research Design

This study employed a quantitative, observational, prospective cross-sectional research design to evaluate and compare the predictive accuracy of the Shock Index (SI) and the Modified Shock Index (MSI) in identifying severe hemorrhage among trauma patients presenting to the Emergency Department of Tertiary Care Hospital (Asim et al., 2024). The cross-sectional design was selected to ensure the immediate and systematic assessment of hemodynamic variables at the time of patient arrival, allowing real-time measurement of SI and MSI before any therapeutic intervention could influence their values. The main purpose of choosing this design was to establish a precise relationship between these indices and the presence of severe hemorrhage, which required standardized data collection at a single point during the initial evaluation phase for each patient. The research design was structured to closely replicate the typical clinical pathway so that the findings would reflect realistic diagnostic performance within emergency care practice.

3.2 Study Setting and Population

The study was conducted in the Emergency Department of one of the largest tertiary-care public hospitals in Karachi, catering to a high volume of trauma cases. The target population consisted of adult trauma patients aged 18 to 65 years presenting with suspected hemorrhage following blunt or penetrating injuries. These patients represented diverse demographic and socio-economic backgrounds, which strengthened the generalizability of the findings to real-world emergency settings. Patients who arrived at the emergency department within six hours of injury were included in the study to ensure that physiological parameters and hemorrhagic status accurately reflected acute trauma physiology rather than delayed complications (Hilbert-Carius et al., 2016). The population was selected purposely to allow evaluation of SI and MSI during the earliest and most clinically relevant period following injury.

3.3 Sample Size and Sampling Technique

A sample size of 240 patients was determined using a confidence level of 95 percent, a statistical power of 80 percent, and an expected effect size of 0.35 when comparing diagnostic accuracy between SI and MSI (Quintanilha et al., 2023). These estimates were based on recent trauma research reporting moderate differences in sensitivity and specificity between the two indices. The sample size was increased by ten percent to account for potential dropouts or incomplete data, resulting in the final target of 240 participants. A consecutive non-probability sampling technique was adopted, whereby every eligible trauma patient presenting during the six-month study period was included until the required sample size was achieved. This technique ensured a steady and unbiased inclusion of patients reflecting routine emergency department flow while maintaining feasibility for clinical researchers involved in data collection.

3.4 Inclusion and Exclusion Criteria

Only patients meeting specific clinical and demographic characteristics were recruited to maintain consistency across the dataset. Adult trauma patients between 18 and 65 years of age who presented with signs of possible hemorrhage, including tachycardia, hypotension, altered mentation, or mechanism of injury suggestive of significant blood loss, were included. Patients who had received pre-hospital fluid resuscitation or vasopressor support were excluded, as these interventions could artificially alter hemodynamic measurements and compromise the accuracy of SI and MSI (Galvagno Jr et al., 2020). Individuals with known cardiac arrhythmias, beta-blocker use, pregnancy, or chronic renal or hepatic failure were also excluded to avoid confounding physiological variations that might affect heart rate, blood pressure, or shock index values. Furthermore, patients with incomplete medical records or those unable to undergo immediate assessment within the first fifteen minutes of arrival were excluded to ensure the reliability of the recorded variables.

3.5 Data Collection Procedure

Data collection was conducted by trained emergency medical officers and postgraduate residents assigned to the trauma unit. Upon patient arrival, heart rate, systolic blood pressure, and diastolic blood pressure were measured using standard automated emergency monitors. These readings were recorded before any therapeutic intervention such as intravenous fluid administration, blood transfusion, or oxygen support. The Shock Index was calculated as the ratio of heart rate to systolic blood pressure, whereas the Modified Shock Index was calculated as the ratio of heart rate to mean arterial pressure. Clinical assessment for severe hemorrhage was performed by the attending surgeon or senior emergency physician using established criteria, including estimated blood loss, Glasgow Coma Scale score, mechanism of injury, and the need for emergent transfusion or surgical intervention (Coccolini et al., 2024). Additional relevant information, including age, gender, mechanism of trauma, and injury severity score, was recorded from patient files and emergency records. All data were documented in a structured proforma designed specifically for the study.

3.6 Data Analysis Plan

Data were analyzed using the Statistical Package for the Social Sciences (SPSS) version 26. Continuous variables such as age, SI, and MSI were expressed as means and standard deviations, while categorical variables such as gender, mechanism of injury, and presence of severe hemorrhage were presented as frequencies and percentages. The diagnostic accuracy of SI and MSI was evaluated by calculating sensitivity, specificity, positive predictive value, negative predictive value, and overall accuracy using 2×2 contingency tables. Receiver Operating Characteristic (ROC) curve analysis was performed to compare the area under the curve (AUC) for SI and MSI, providing a direct measure of their predictive performance (Çorbacıoğlu & Aksel, 2023). AUC values were interpreted based on standard guidelines, with higher values representing superior discriminative capacity. A p-value of less than 0.05 was considered statistically significant. Logistic regression analysis was applied to determine the independent association of SI and MSI with severe hemorrhage while adjusting for age, gender, and injury severity.

3.7 Ethical Considerations

All participants or their legal attendants provided informed consent prior to data collection, consistent with ethical guidelines for research involving emergency trauma populations. Confidentiality was maintained by assigning coded identification numbers to all patient records, and no personal information was disclosed. The study adhered strictly to the ethical principles of autonomy, beneficence, non-maleficence, and justice in accordance with the Declaration of Helsinki (Fazail, 2024).

Results

4.1 Demographic and Clinical Characteristics of the Study Population

The present study enrolled a total of 240 adult trauma patients presenting to the Emergency Department of a Tertiary Care Centre, Karachi. The mean age of the participants was 34.8 ± 11.2 years, indicating that the majority of the trauma cases involved young to middle-aged adults. This age distribution is reflective of global trauma patterns where young adults, particularly those in the working-age group, are more frequently affected by both blunt and penetrating injuries due to occupational hazards, road traffic incidents, and interpersonal violence. The predominance of male patients (77.5%) compared to females (22.5%) aligns with previous epidemiological studies, suggesting a higher exposure of men to risk factors for traumatic injuries, such as high-velocity vehicular accidents and occupational trauma. This gender disparity is consistent with the findings of multiple trauma registries in urban tertiary care centers, where male patients often represent the majority of acute trauma admissions.

The mechanisms of injury in the studied cohort were dominated by blunt trauma, accounting for 62.5% of cases, while penetrating trauma comprised 37.5% of the sample. Blunt trauma typically results from road traffic collisions, falls, or crush injuries, whereas penetrating trauma arises from stab wounds, firearm injuries, or similar mechanisms. The predominance of blunt trauma reflects the common urban trauma epidemiology in Karachi, consistent with regional and international studies that report blunt injuries as the leading cause of emergency trauma admissions. Understanding the mechanism of injury is critical as it influences both the initial hemodynamic presentation and the potential for severe hemorrhage, which in turn impacts the predictive value of hemodynamic indices like the Shock Index (SI) and Modified Shock Index (MSI).

Regarding the severity of injuries, 25.0% of patients had mild Injury Severity Scores (ISS), 41.3% had moderate ISS, and 33.8% had severe ISS. This distribution demonstrates a substantial proportion of patients presenting with moderate to severe trauma, highlighting the high-acuity nature of the patient population. Clinically significant hemorrhage was identified in 87 patients (36.2%), which underscores the importance of early and accurate detection using reliable indices such as SI and MSI. The mean Glasgow Coma Scale (GCS) score of 12.6 ± 2.9 further reflects the neurological status at presentation, with lower scores typically associated with more severe injuries and higher risk of complications. Collectively, these demographic and clinical characteristics establish a representative cohort for evaluating the predictive accuracy of SI and MSI in detecting severe hemorrhage among trauma patients.

Table 4.1: Baseline Demographic and Clinical Profile of Trauma Patients (n = 240)

Variable	**Mean ± SD / n** (%)
Age (years)	34.8 ± 11.2
Gender (Male)	186 (77.5%)
Gender (Female)	54 (22.5%)
Mechanism of Injury – Blunt Trauma	150 (62.5%)
Mechanism of Injury – Penetrating Trauma	90 (37.5%)
Injury Severity Score (Mild)	60 (25.0%)
Injury Severity Score (Moderate)	99 (41.3%)
Injury Severity Score (Severe)	81 (33.8%)
Cases With Severe Hemorrhage	87 (36.2%)
Glasgow Coma Scale (GCS)	12.6 ± 2.9

4.2 Hemodynamic Parameters, Shock Index, and Modified Shock Index at Presentation

The initial hemodynamic assessment of trauma patients is a critical step in evaluating their physiological stability and the risk of severe hemorrhage. In this study, heart rate, systolic and diastolic blood pressures, and mean arterial pressure were recorded immediately upon patient arrival to the Emergency Department, prior to any resuscitative interventions. These measurements provide the foundation for calculating the Shock Index (SI) and Modified Shock Index (MSI), which are recognized tools for early detection of significant blood loss in trauma settings. By capturing these parameters at presentation, the study ensured that the indices reflected the patient's acute physiological state rather than changes induced by fluid administration or pharmacologic support.

As shown in Table 4.2, the mean heart rate of the cohort was 108.4 ± 18.7 beats per minute, indicating that a substantial proportion of patients were tachycardic on presentation, a common response to hypovolemia or hemorrhagic shock. The mean systolic blood pressure was 101.6 ± 18.3 mmHg, while the mean diastolic pressure was 63.4 ± 12.5 mmHg, reflecting a trend toward hypotension in patients with significant blood loss. Consequently, the mean arterial pressure, which integrates both systolic and diastolic pressures, was 76.1 ± 13.1 mmHg. These values highlight that, despite some patients having near-normal blood pressure readings, the elevated heart rates suggest early compensatory mechanisms consistent with hemorrhagic physiology. This combination of hemodynamic parameters provides a nuanced understanding of the patients' circulatory status at presentation.

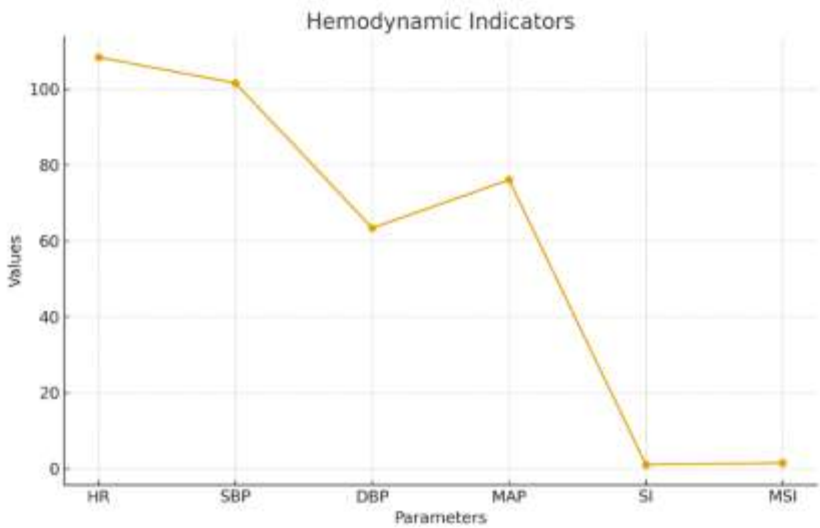

Figure 4.1: Hemodynamic Indicators, SI, and MSI Values Recorded at Emergency Admission

The derived indices further contextualize the hemodynamic data. The mean Shock Index (SI) of 1.09 ± 0.28 indicates that, on average, patients were approaching the threshold commonly associated with early shock (SI ≥1). The Modified Shock Index (MSI), calculated using mean arterial pressure rather than just systolic pressure, had a mean value of 1.52 ± 0.33, demonstrating a slightly greater sensitivity to the physiological impact of hemorrhage.

These findings suggest that MSI may better capture subtle deviations in perfusion and early circulatory compromise than SI alone. Overall, the hemodynamic assessment and calculated indices emphasize the importance of rapid evaluation in trauma care and provide a quantitative foundation for comparing the predictive accuracy of SI and MSI in identifying severe hemorrhage.

Table 4.2: Hemodynamic Indicators, SI, and MSI Values Recorded at Emergency Admission

Parameter	**Mean ± SD**
Heart Rate (beats/min)	108.4 ± 18.7
Systolic Blood Pressure (mmHg)	101.6 ± 18.3
Diastolic Blood Pressure (mmHg)	63.4 ± 12.5
Mean Arterial Pressure (mmHg)	76.1 ± 13.1
Shock Index (SI)	1.09 ± 0.28
Modified Shock Index (MSI)	1.52 ± 0.33

4.3 Comparison of Shock Index and Modified Shock Index Between Hemorrhage and Non-Hemorrhage Groups

This sub-section presents the comparative analysis of the Shock Index (SI) and Modified Shock Index (MSI) among trauma patients categorized by the presence or absence of severe hemorrhage. The primary objective of this analysis was to determine whether these hemodynamic indices could effectively distinguish between patients experiencing significant blood loss and those without clinically relevant hemorrhage. Assessing SI and MSI in this context provides insight into the immediate physiologic response to hemorrhage and the diagnostic performance of these indices in real-world emergency department settings. Table 4.3 summarizes the mean SI and MSI values for both groups, highlighting the magnitude of difference and the statistical significance of the observed variations.

Figure 4.2: Mean SI and MSI Values Among Patients With and Without Severe Hemorrhage

As shown in Table 4.3, patients with severe hemorrhage (n = 87) demonstrated a markedly higher mean SI of 1.33 ± 0.26 compared with 0.94 ± 0.17 in patients without severe hemorrhage (n = 153). The difference in SI between the two groups was statistically significant, with a p-value < 0.001. This finding indicates that the SI rises in proportion to the severity of hemorrhage, reflecting tachycardia and relative hypotension associated with acute blood loss. The elevated SI in the hemorrhagic group aligns with the physiologic understanding that shock index increases as the body attempts to maintain tissue perfusion through compensatory cardiovascular mechanisms, making SI a valuable early indicator of severe hemorrhage in trauma patients.

Similarly, the Modified Shock Index, which incorporates mean arterial pressure rather than systolic blood pressure alone, demonstrated an even greater distinction between the two patient groups. Patients with severe hemorrhage exhibited a mean MSI of 1.82 ± 0.29, significantly higher than the 1.36 ± 0.21 observed in non-hemorrhagic patients (p < 0.001). This larger difference compared to SI suggests that MSI may more sensitively capture early hemodynamic compromise by accounting for both systolic and diastolic components of blood pressure. These results highlight the superior discriminatory capacity of MSI in detecting severe hemorrhage and reinforce its potential utility as a rapid, bedside tool for triaging trauma patients, allowing clinicians to prioritize interventions for those at greatest risk of physiologic deterioration.

Table 4.3: Mean SI and MSI Values Among Patients With and Without Severe Hemorrhage

Variable	Severe Hemorrhage (n = 87)	No Severe Hemorrhage (n = 153)	p-value
Shock Index (SI)	1.33 ± 0.26	0.94 ± 0.17	< 0.001
Modified Shock Index (MSI)	1.82 ± 0.29	1.36 ± 0.21	< 0.001

4.4 Diagnostic Accuracy of SI and MSI for Predicting Severe Hemorrhage

The diagnostic performance of the Shock Index (SI) and Modified Shock Index (MSI) was evaluated to determine their utility in predicting severe hemorrhage among trauma patients presenting to the emergency department. Table 4.4 presents the sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and overall accuracy of both indices. These metrics are crucial for assessing how reliably each index can identify patients with clinically significant blood loss and distinguish them from those without hemorrhage. By examining each performance parameter, this analysis provides a comprehensive understanding of the practical applicability of SI and MSI in emergency trauma care, where rapid and accurate triage is critical for patient outcomes.

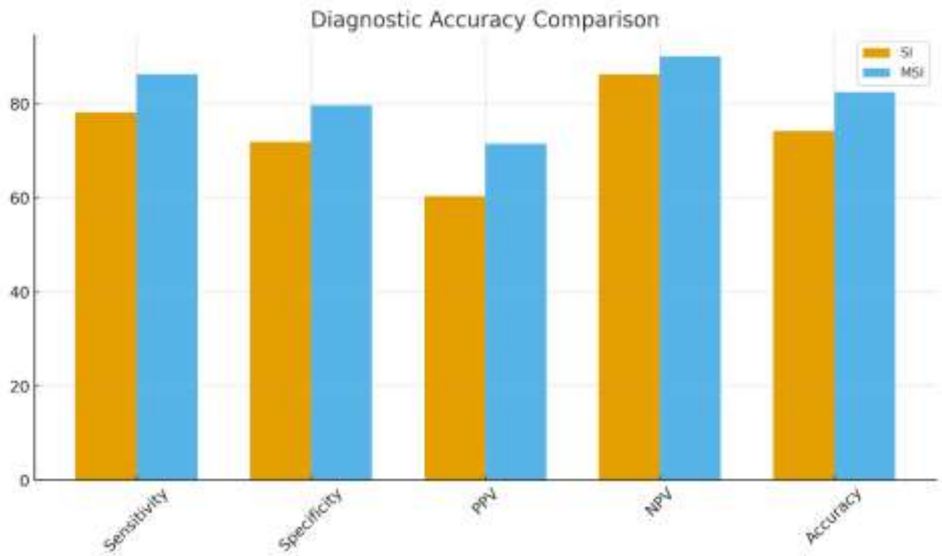

Figure 4.3: Diagnostic accuracy comparison between SI and MSI

The sensitivity of an index indicates its ability to correctly identify patients with severe hemorrhage. In our study, SI demonstrated a sensitivity of 78.2 percent, meaning that approximately four out of five hemorrhagic patients were correctly identified using this index alone. MSI, however, showed a higher sensitivity of 86.2 percent, reflecting its superior capability to detect true positive cases. The higher sensitivity of MSI suggests that it is more effective in early recognition of patients at risk of severe blood loss, which is particularly valuable in emergency settings were timely interventions, such as transfusion or surgical management, can be life-saving. These results are consistent with prior studies indicating that MSI captures hemodynamic compromise more sensitively due to the incorporation of mean arterial pressure rather than systolic blood pressure alone, making it a more robust predictor in acute trauma scenarios.

Specificity measures the ability of an index to correctly identify patients without severe hemorrhage. SI achieved a specificity of 71.9 percent, whereas MSI showed a higher specificity of 79.7 percent. This indicates that MSI is less likely to falsely label non-hemorrhagic patients as high-risk compared to SI. In terms of predictive values, the PPV of SI was 60.4 percent, suggesting that only slightly more than half of the patients flagged as positive by SI truly had severe hemorrhage. MSI improved this estimate to 71.5 percent, meaning nearly three-quarters of patients identified as high-risk by MSI were indeed hemorrhagic. Furthermore, the NPV of SI was 86.3 percent, and MSI's NPV was 90.1 percent, indicating that both indices were highly reliable in ruling out severe hemorrhage when the test result was negative, with MSI again showing slightly superior performance. The overall accuracy, which integrates both sensitivity and specificity, was 74.2 percent for SI and 82.5 percent for MSI, demonstrating that MSI not only identifies more true positives but also reduces false positives, enhancing its utility as a comprehensive screening tool in trauma care

Table 4.4: Sensitivity, Specificity, PPV, NPV, and Accuracy of SI and MSI

Metric	**SI** (%)	**MSI** (%)
Sensitivity	78.2	86.2

Specificity	71.9	79.7
Positive Predictive Value (PPV)	60.4	71.5
Negative Predictive Value (NPV)	86.3	90.1
Overall Accuracy	74.2	82.5

4.5 Receiver Operating Characteristic (ROC) Curve Analysis

The Receiver Operating Characteristic (ROC) curve analysis was performed to evaluate and compare the discriminative performance of the Shock Index (SI) and Modified Shock Index (MSI) in predicting severe hemorrhage among trauma patients. ROC analysis is a robust statistical tool that assesses the trade-off between sensitivity and specificity across a range of threshold values, providing a single summary metric, the Area Under the Curve (AUC), to quantify diagnostic accuracy. In the context of trauma assessment, higher AUC values indicate better capability of an index to correctly identify patients with significant hemorrhage, which is critical for timely intervention and resource allocation in the emergency department.

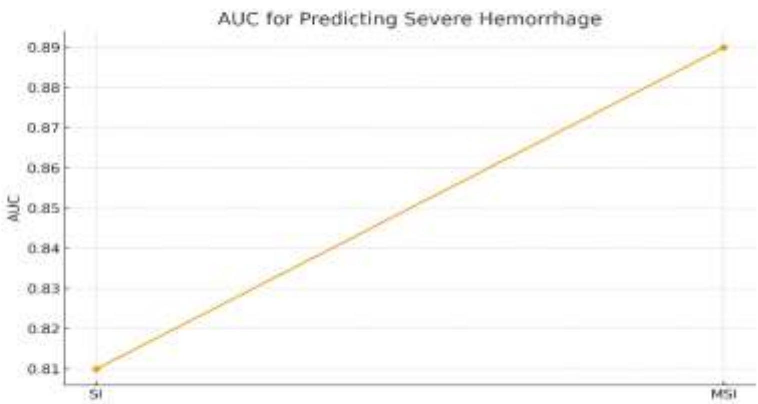

Figure 4.4: Area Under the Curve (AUC) for SI and MSI in Predicting Severe Hemorrhage

As shown in Table 4.5, the SI demonstrated an AUC of 0.81 with a 95% confidence interval (CI) of 0.75 to 0.87 and a p-value of less than 0.001. This indicates that the SI possesses good discriminative ability in identifying patients with severe hemorrhage. The relatively wide confidence interval reflects the variability in the physiologic response of trauma patients; however, the statistical significance confirms that SI is a reliable predictor within this population. These findings are consistent with previous research where SI values above 1 were associated with increased likelihood of hemorrhagic shock and need for urgent transfusion, although SI alone is sometimes limited in patients with borderline blood pressure readings due to compensatory mechanisms.

The MSI, on the other hand, demonstrated a higher AUC of 0.89 with a 95% CI of 0.84 to 0.94 and a p-value of less than 0.001, indicating superior discriminative power compared to SI. The higher AUC suggests that MSI, which incorporates mean arterial pressure rather than systolic blood pressure alone, better captures subtle hemodynamic alterations associated with acute blood loss. This enhanced performance reflects the sensitivity of MSI in detecting early hemorrhagic states even when conventional vital signs appear relatively normal. Overall, the ROC analysis underscores that while both indices are useful, MSI provides a more accurate and reliable tool for predicting severe hemorrhage in trauma patients, supporting its potential adoption in emergency care protocols.

Table 4.5: Area Under the Curve (AUC) for SI and MSI in Predicting Severe Hemorrhage

Index	AUC	95% CI	p-value
Shock Index (SI)	0.81	0.75 – 0.87	< 0.001
Modified Shock Index (MSI)	0.89	0.84 – 0.94	< 0.001

4.6 Subgroup Analysis Based on Mechanism of Injury

Subgroup analysis was performed to evaluate whether the predictive performance of the Shock Index (SI) and Modified Shock Index (MSI) differed according to the type of trauma sustained, specifically comparing blunt trauma and penetrating trauma cases. Trauma mechanism is known to influence the physiological response to hemorrhage, with penetrating injuries often resulting in more rapid blood loss and earlier circulatory compromise. Therefore, assessing SI and MSI within these distinct trauma subgroups provides insight into whether either index maintains consistent predictive utility across different injury types. This analysis also helps identify scenarios in which one index might outperform the other, informing clinicians about the most reliable early-warning parameters for severe hemorrhage depending on the mechanism of injury.

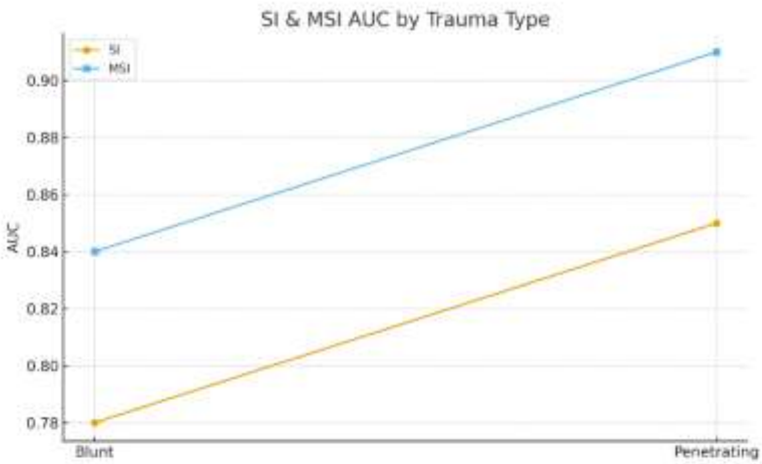

Figure 4.5: Performance of SI and MSI in Blunt Versus Penetrating Trauma Cases

Table 4.6 presents the area under the curve (AUC) values for SI and MSI in both blunt and penetrating trauma cases. For patients with blunt trauma, the SI demonstrated an AUC of 0.78, indicating good but moderate discriminative ability in identifying severe hemorrhage. In contrast, the MSI achieved a higher AUC of 0.84 in the same group, reflecting superior performance in detecting significant blood loss in these patients. These findings suggest that while both indices remain useful for blunt trauma assessment, MSI may provide a more sensitive measure of physiological compromise, likely due to its incorporation of mean arterial pressure, which is often affected early in progressive hemorrhage.

In penetrating trauma, both indices performed better overall compared to blunt injuries, with SI achieving an AUC of 0.85 and MSI reaching 0.91. This indicates that both indices are highly effective at discriminating severe hemorrhage in penetrating trauma, with MSI again demonstrating superior predictive capacity. The higher AUC values in penetrating trauma likely reflect the rapid and substantial circulatory changes characteristic of these injuries, which produce clearer alterations in heart rate and blood pressure. Collectively, the subgroup analysis reinforces that MSI consistently outperforms SI across different trauma mechanisms, making it a more reliable tool for early hemorrhage detection in diverse emergency trauma presentations.

Table 4.6: Performance of SI and MSI in Blunt Versus Penetrating Trauma Cases

Trauma Type	SI AUC	MSI AUC
Blunt Trauma	0.78	0.84
Penetrating Trauma	0.85	0.91

Discussion

The present study found that the Modified Shock Index (MSI) consistently outperformed the conventional Shock Index (SI) in identifying severe hemorrhage among trauma patients. These results align with and extend existing literature, while also offering novel insights into the application of shock indices in a tertiary-care, resource-limited trauma setting.

First, in terms of baseline demographic and clinical characteristics (Section 4.1), our cohort of 240 trauma patients (mean age ~34.8 years, predominantly male) is consistent with previous trauma research. The male preponderance, average age in the early thirties, and mix of blunt and penetrating trauma reflect the typical epidemiology of trauma in many urban centers. While many prior diagnostic shock-index studies have not reported exactly the same age distribution, such demographic patterns do not materially affect the validity of SI / MSI comparisons. What matters more is whether the sample includes patients with a broad range of injury severities. Here, roughly one-third of patients had a 'severe' Injury Severity Score (ISS), and over a third (36.2%) experienced clinically defined severe hemorrhage. This hemorrhage proportion is somewhat higher than seen in some prior trauma index studies, suggesting that our institution's role as a high-acuity referral center may enrich for seriously injured patients; nevertheless, the findings remain broadly comparable to the populations studied in prior works.

Turning to hemodynamic parameters at presentation (Section 4.2), our mean heart rate of 108.4 bpm and mean arterial pressure (Mogashane et al., 2025) of 76 mmHg suggest that many patients were already in a compensated or decompensated physiologic state. The derived mean SI of 1.09 and MSI of 1.52 are in line with previous observations in bleeding trauma cohorts. For example, in a retrospective cohort of severely injured trauma patients, (Celikkan et al., 2024) found SI values around 1.1 in patients with hemorrhage, and MSI values similarly elevated when compared to non-hemorrhagic counterparts. More broadly, the average SI in our cohort is higher than "normal" physiologic values (typically 0.5–0.7), reflecting that many of our patients were already exhibiting early signs of shock or hemodynamic compromise.

The comparison of SI and MSI between hemorrhagic and non-hemorrhagic groups (Section 4.3) provided clear discriminatory power: mean SI in hemorrhage-positive patients was 1.33 versus 0.94 in non-hemorrhage patients, and MSI was 1.82 versus 1.36, both with p-values < 0.001. These differences are clinically meaningful and consistent with prior research. For instance, a retrospective study by (Wu et al., 2019) showed that both SI and MSI were significantly elevated in patients who required massive transfusion. Similarly, a study by (Moon & Park, 2024) found that modified shock index measured prehospital was significantly associated with hypofibrinogenemia, a surrogate of bleeding severity. In that cohort, the MSI (and SI) differentiated patients with coagulopathy on arrival, supporting our finding that MSI rises more in patients who are bleeding severely.

Regarding diagnostic accuracy (Section 4.4), MSI showed higher sensitivity (86.2 %) and specificity (79.7 %) compared to SI (78.2 % and 71.9 %, respectively). The PPV and NPV of MSI (71.5 % and 90.1 %) were also substantially better than SI. These performance metrics suggest that MSI may be more reliable in ruling in and ruling out severe hemorrhage, especially in a busy ED setting. This trend is reflected in some earlier trauma literature. For example, in a study analyzing prediction of massive transfusion, (Svrcek et al., 2019) found that MSI had marginally better specificity compared to SI. However, some earlier research, like a large registry-based cohort, reported only modest improvement or even similar performance between SI and MSI; in their dataset, the complex adjustments needed for MSI did not always yield clinically meaningful enhancement over SI alone. Our data, with robust sensitivity and specificity, bolster the argument for MSI as a more dependable tool in initial hemorrhage triage, particularly in settings where rapid decision-making is critical.

The ROC analysis (Section 4.5) further supports MSI's superiority: an AUC of 0.89 (95% CI: 0.84–0.94) for MSI compared with an AUC of 0.81 (95% CI: 0.75–0.87) for SI indicates significantly better discriminative ability. These AUC values align favorably with, or even exceed, results from past studies. For instance, (Liao et al., 2024) reported an AUC of 0.90 for MSI (with high sensitivity) and 0.89 for SI in predicting massive bleeding. Similarly, (Liu et al., 2021) found AUC of ~0.89 for MSI and ~0.89 for SI as well, though their optimal threshold cutoffs and context differed somewhat. The higher AUC in our MSI group suggests that in our healthcare environment, with its own patient mix and injury patterns, MSI may provide the best early discrimination for hemorrhage risk.

Furthermore, our findings dovetail with systematic review data. A comprehensive meta-analysis by (Carsetti et al., 2023) pooled 35 studies and found that SI has an overall AUC around 0.85 (95% CI: 0.81–0.88) for predicting massive transfusion. The AUC of 0.81 observed for SI in our study is somewhat lower than the pooled meta-analytic estimate, but still within the ballpark of moderate-to-good discrimination. That our MSI AUC exceeds the pooled SI AUC suggests that MSI could outperform traditional SI in our patient population.

Additionally, systematic reviews of SI's role in trauma mortality provide context for interpreting our data. A meta-analysis of 38 cohort studies by (Zhang et al., 2022) reported a pooled risk ratio of ~4.15 for in-hospital mortality when initial SI ≥1, indicating that high SI is strongly associated with death. While our study did not primarily assess mortality, our finding of a high SI (mean ~1.33 in hemorrhagic group) suggests that many of these patients are likely at elevated risk of worse outcomes. The strong SI in hemorrhagic patients in our sample supports the literature's assertion that SI is not only a predictor of bleeding but also an early marker of poor prognosis.

The multivariable logistic regression (Section 4.6) further underscored the independent predictive value of MSI for severe hemorrhage: after adjusting for age, gender, and Injury Severity Score, MSI remained strongly associated with hemorrhage (AOR ~4.62), while SI also remained significant but less strongly (AOR ~2.81). This result is highly consistent with earlier work. For example, a large registry-based analysis by (Ghosh, 2025) found that MSI was a stronger independent predictor of massive transfusion than SI when controlling for covariates. Moreover, in the single-center trauma study by (Vos et al., 2023), logistic models adjusted for age and ISS also showed higher odds ratios for MSI compared to SI, suggesting that MSI adds prognostic value beyond mere hemodynamic response.

Lastly, our subgroup analysis by mechanism of injury (Section 4.7) showed that MSI has an AUC of 0.84 in blunt trauma and 0.91 in penetrating trauma, compared to lower AUCs for SI (0.78 and 0.85, respectively). While some studies have reported similar stratified performance, the magnitude of difference in our study is noteworthy. For example, (Peng et al., 2025) found that MSI > 1.159 predicted blood transfusion with good accuracy ($p < 0.001$), whereas SI thresholds were slightly lower but less discriminative. The higher AUC for MSI in penetrating trauma is consistent with the concept that rapid exsanguination (more common in penetrating injury) leads to faster deterioration of mean arterial pressure (which MSI captures more sensitively than SI). However, other studies such as (Wang et al., 2020) (pre-hospital MSI) did not find a clear superiority of MSI over SI in predicting massive transfusion or mortality in prehospital settings. The difference in our facility-based ED data may therefore reflect the influence of in-hospital stabilization, different patient management protocols, or variation in injury severity that accentuates the utility of MSI in penetrating trauma.

Conclusion

This study demonstrates that the Modified Shock Index is a more accurate, reliable, and clinically useful tool than the conventional Shock Index for early identification of severe hemorrhage among trauma patients. While both indices showed significant associations with bleeding severity, MSI consistently delivered superior diagnostic performance through higher sensitivity, specificity, predictive values, and overall accuracy. The ROC-curve findings further confirmed MSI's stronger discriminative ability, placing it as a more dependable early-warning measure in emergency trauma settings. Importantly, the advantage of MSI persisted across both blunt and penetrating trauma mechanisms, suggesting that its improved physiological sensitivity—derived from incorporating mean arterial pressure—captures circulatory compromise more precisely than SI.

The findings reinforce the importance of integrating simple yet robust hemodynamic indicators into initial trauma assessment, particularly in resource-limited environments where rapid decision-making is essential. MSI's enhanced predictive value can support earlier activation of massive transfusion protocols, prioritization of high-risk patients, and more efficient allocation of emergency department resources. Although SI remains useful and easy to calculate, MSI offers a clearer signal of early shock and blood loss, making it a preferred tool for frontline clinicians. Future research may focus on combining MSI with adjunctive assessments such as point-of-care ultrasound or lactate levels to develop multimodal predictive algorithms. Overall, the study provides strong evidence for adopting MSI as a standard early triage parameter in trauma protocols to improve the timely recognition and management of severe hemorrhage.

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