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Shock Index as a Predictor of Mortality and Hospital Admission in Prehospital Gastrointestinal Bleeding: A Retrospective Cohort Study

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ABSTRACT

Objective: To evaluate the Shock Index (SI) as a predictive tool for triage of gastrointestinal bleeding (GI) in the prehospital setting, assessing its correlation with mortality, admission rates, and hospital length of stay.

Methods: In this retrospective cohort study, we analyzed data from the ESO Data Collaborative encompassing EMS records from the year 2022, focusing on 1525 patients with a primary GI bleeding diagnosis. The primary measure was the SI, calculated at initial contact and highest recorded prior to ED arrival. Statistical analysis included t-tests, linear regression, and ROC curves, performed using SPSS v29.

Results: A significantly higher mean SI was observed in patients who died (mean SI 0.997) compared to survivors (mean SI 0.795), $p < 0.001$. Admission rates also correlated with higher SI values, $p < 0.001$. However, SI was not predictive of the hospital length of stay. ROC analysis for mortality prediction yielded an AUC of 0.656 for the initial SI and 0.739 for the highest SI. The standard SI cutoff of 0.9 predicted mortality with a sensitivity of 74.14% and specificity of 55.35% for the highest SI.

Conclusion: The SI is a valuable predictive tool for mortality among prehospital patients with GI bleeding. Its application may improve the triage process, potentially influencing transport decisions and initial hospital care. Despite its predictive capability for mortality, the SI should be supplemented with other clinical assessments to make comprehensive prehospital care decisions. Further research into SI as part of a comprehensive assessment which includes end-title CO2, mentation, and heaviness of bleeding.

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Background

Gastrointestinal (GI) bleeding is a common and potentially life-threatening medical emergency that requires prompt and accurate assessment to determine the severity and guide appropriate management (1, 2). Gastrointestinal (GI) bleeding represents a significant clinical challenge with an incidence rate of approximately 173.5 cases per 100,000 population, with a substantial hospitalization rate of 160.3 hospitalizations per 100,000 population annually, and is associated with a notable case fatality rate, ranging between 2.7% and 3.7% (1, 2). In the emergency room, established evaluation tools such as the Glasgow-Blatchford Score (GBS) and the AIMS65 are employed to risk-stratify patients with GI bleeds (3, 4). These scoring systems are effective but depend heavily on laboratory tests, which are not feasible in the prehospital environment due to logistical constraints.

Our study explores the potential of the Shock Index (SI), a simple, rapid, and non-laboratory-based tool, as a predictive measure in the prehospital setting. The SI, calculated as the ratio of heart rate (HR) to systolic blood pressure (SBP), is a readily obtainable parameter that can provide immediate insights into a patient's hemodynamic status. The SI has shown promise as a predictor of mortality in geriatric patients with upper GI bleeds (5). Despite its simplicity, it has not been widely explored as a standalone predictor for the severity of GI bleeding in the resource-limited prehospital context.

We defined "high risk" as death, need for admission, and increased hospital length of stay (LOS). Our definition is based upon the initial study on the AIMS65 scoring system which highlighted its utility in predicting hospital mortality, LOS, and health care costs associated with GI bleeding, thus categorizing patients into high and low-risk groups (4). These are patient-oriented outcomes that are critical for guiding emergency care and resource allocation but are challenging to assess outside hospital settings.

Utilizing a comprehensive database provided by ESO Solutions, which includes data on mortality, admission rates, and LOS, our study aims to validate the effectiveness of the SI in identifying high-risk GI bleeding patients in the prehospital setting. We hypothesize that a higher SI correlates with increased mortality, a higher likelihood of hospital

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admission, and prolonged hospital stays, thus allowing first responders and emergency medical services (EMS) to triage and manage these patients more effectively.

In this paper, we aim to enhance the prehospital care of patients with GI bleeding, optimizing their outcomes by facilitating early recognition of high-risk cases and informing timely medical interventions. Our findings present a detailed analysis of the SI as a predictive tool for the severity of GI bleeding in the prehospital setting.

Methods

Study Design and Setting

This retrospective cohort study was conducted using public use datasets provided by the ESO Data Collaborative (ESO, Austin, Texas) encompassing data from the calendar year 2022. The ESO Data Collaborative is a comprehensive, multi-institutional database that collects prehospital care records from nearly 2000 EMS agencies across various regions. These data are collected in accordance with the NEMSIS v3 data standard. This study was designed to investigate the application of the SI in prehospital settings for patients with GI bleeding.

Study Population

We evaluated the entire ESO EMS dataset ($n = 11{,}109{,}058$) and identified a potential study population with a primary or secondary diagnosis of GI bleeding ($n = 2992$), as classified under the ICD-10 codes K92.2 (Gastrointestinal hemorrhage, unspecified), K25.0-K25.9 (Gastric ulcer with various complications), K26.0-K26.9 (Duodenal ulcer with various complications), K27.0-K27.9 (Peptic ulcer, site unspecified, with various complications), K28.0-K28.9 (Gastro-jejunal ulcer with various complications), I85.11 (Esophageal varices with bleeding) and K62.5 (Hemorrhage of anus and rectum). Patients were excluded from the study if they were under 18 years of age ($n = 573$) or had incomplete data regarding vital signs ($n = 896$). These inclusion and exclusion criteria ensured a focused study population specifically dealing with GI bleeding incidents, with a final study population of 1525 patients.

Ethical Considerations

As the study involved retrospective analysis of de-identified data, it was classified as exempt from full review by the University of Texas Health Science Center San Antonio (UTHSCSA) Institutional Review Board (IRB). However, all data handling procedures strictly adhered to the guidelines for the ethical use of secondary data.

Study Variables

The primary independent variable was the SI, calculated as the ratio of HR to SBP at the time of initial EMS contact as well as the highest SI documented prior to ED arrival. Dependent variables included hospital admission rates, hospital LOS, and mortality rates.

Statistical Analysis

The statistical methods employed in our study utilized SPSS software, version 29 (IBM Corp., Armonk, N.Y., USA). Prior to analysis, data were cleaned and screened for accuracy and completeness. Missing data were handled according to the nature and extent of the missingness, either through imputation or case exclusion, based on the predefined criteria. Descriptive statistics were generated to provide an overview of the study population. This included means and standard deviations for continuous variables. Linear regression was used to investigate the relationship between the SI and continuous dependent variables such as hospital LOS. Assumptions of linear regression, including linearity, homoscedasticity, and normality of residuals, were tested. Results were expressed as regression coefficients with 95% confidence intervals. Independent t-tests were conducted to compare mean values of continuous variables between two groups, such as comparing vital signs between survivors and non-survivors. Assumptions of normality and homogeneity of variances were tested, and results were reported as mean differences with 95% confidence intervals. Box plots were generated to visually assess the distribution of continuous variables, such as the SI across different outcomes (e.g., mortality, length of stay). These plots provided insights into the central tendency, spread, and potential outliers in the data. Receiver Operating Characteristic (ROC) analysis was performed to evaluate the diagnostic ability of the SI in predicting specific outcomes like mortality. The area under the ROC curve (AUC) was calculated to quantify the overall diagnostic accuracy. An AUC of 1 indicates perfect discrimination, whereas an AUC of 0.5 suggests no discriminative power. The sensitivity and specificity of the SI were calculated at various threshold levels to identify the optimal cut-off point for predicting outcomes like hospital admission or mortality. These metrics were crucial in assessing the practical utility of the SI in the prehospital setting. All tests were two-tailed, and a p-value of less than 0.05 was considered statistically significant. The results were carefully interpreted and reported, adhering to the standards of reporting statistical findings in medical research.

Results

There were 1525 patient encounters that met all inclusion and exclusion criteria. The mean age was 67 (IQR 60–82), 48.2% female.

Initial Recorded SI

When comparing mortality outcomes (lived vs. died prior to hospital discharge), patients who died ($n = 59$) had a significantly higher mean SI (0.997, SD 0.395) compared to those who lived ($n = 1466$, mean SI 0.795, SD 0.292). The mean difference in SI between these groups was 0.202 (95% CI

0.097 to 0.307, $p < 0.001$; Figure 1). The area under the ROC curve for mortality prediction using the initial SI was 0.656 (Figure 2).

For hospital admission outcomes (admitted vs. discharged from the emergency department), admitted patients ($n = 1184$) showed a higher mean SI (0.822, SD 0.308) than those discharged ($n = 341$, mean SI 0.738, SD 0.254). The mean difference was 0.084 (95% CI 0.051 to 0.116, $p < 0.001$; Figure 3) the area under the ROC of 0.578 (Figure 4).

Linear regression analysis showed no significant association between the initial SI and hospital LOS (Standardized coefficient beta 0.043, 95% CI −0.826 to 2.248, p 0.639; Figure 5).

Highest Recorded SI

When assessing the highest recorded SI, a more pronounced difference was observed in mortality outcomes. Patients who died had a mean SI of 1.350 (SD 0.5692), significantly higher than those who lived (mean SI 0.9302, SD 0.363; Figure 6). The mean difference was 0.420 (95% CI 0.269 to 0.571, $p < 0.001$), with an area under the ROC curve of 0.739 (Figure 2).

Regarding admission rates, admitted patients had a mean highest SI of 0.968 (SD 0.388), compared to 0.870 (SD 0.349) in discharged patients (Figure 7). The mean difference was 0.098 (95% CI 0.052 to 0.144, $p < 0.001$), with an area under the ROC of 0.583 (Figure 4).

Similar to the initial SI, linear regression analysis for the highest SI revealed no significant relationship with the hospital LOS (Standardized coefficient beta −0.022, 95% CI −1.514 to 0.929, p 0.364; Figure 8).

Predictive Values at a Standard Cutoff of 0.9 for SI

We used a standard cutoff of 0.9 for SI in terms of predicting mortality (3.9% prevalence in this cohort) (5). For the highest documented SI, the sensitivity was 74.14%, specificity 55.35%, positive predictive value (PPV) 6.31%, negative predictive value (NPV) 98.14%, and Odds Ratio (OR) 3.554 (95%CI 1.957–6.456). For the initial SI, the sensitivity was 51.72%, specificity 71.16%, PPV 6.78%, NPV 97.32%, and OR 2.644 (95%CI 1.560–4.480).

We used the same cutoff for predicting admissions (77.7% prevalence in this cohort). For the highest SI, the sensitivity was 48.58%, specificity 63.96%, PPV 82.45%, NPV 26.31%, and OR 1.677 (95%CI 1.304–2.157). For the initial SI, the sensitivity was 32.36%, specificity 79.4%, PPV 84.55%, NPV 25.20%, and OR 1.844 (95%CI 1.377–2.469).

These findings suggest that the prehospital shock index (especially one that is trending up) is a potential predictor of mortality in patients with GI bleeding in the prehospital setting. However, both measures showed limited predictive value for hospital admission and no significant association with the hospital LOS.

Discussion

The results of our study, utilizing comprehensive data from the ESO Data Collaborative, provide crucial insights into the applicability of the SI in the prehospital setting for identifying potentially critical patients with GI bleeding, particularly those with ongoing hemorrhage. While one might assume that patients presenting with more severe shock would invariably face worse long-term prognoses, our findings underscore the SI's potential as a valuable tool in the prehospital triage process for these patients.

Utility in Identifying the Severity of GI Bleeds

The SI's significant correlation with mortality in GI bleeding patients, as indicated by our results, highlights its utility in identifying patients who are potentially experiencing severe

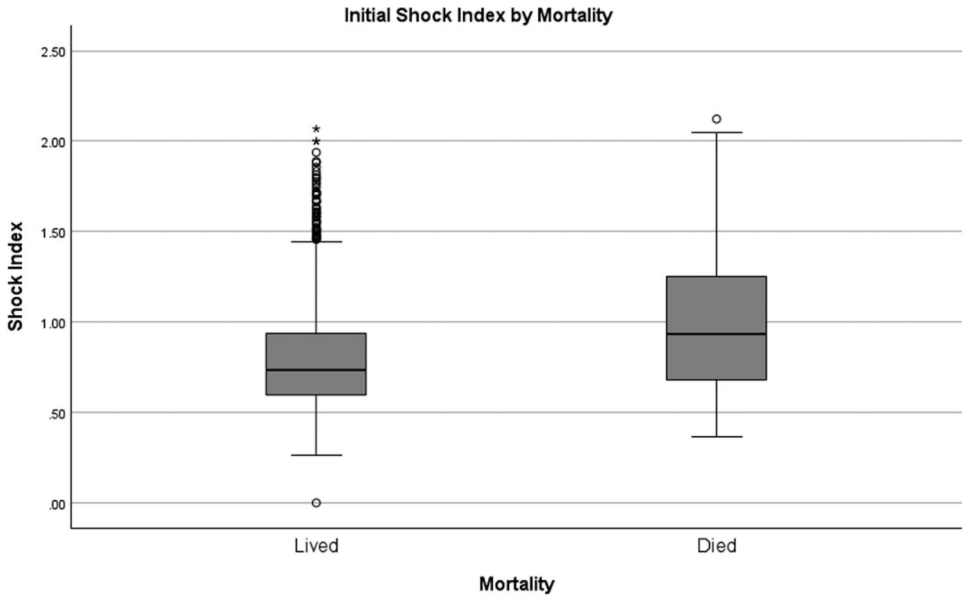


Figure 1. Initial shock index by mortality. Box plots showing the Initial SI mean and IQR for those who lived was significantly lower than those who died, though there were some outliers (represented by the circles) and extreme outliers (as represented by the asterisks).

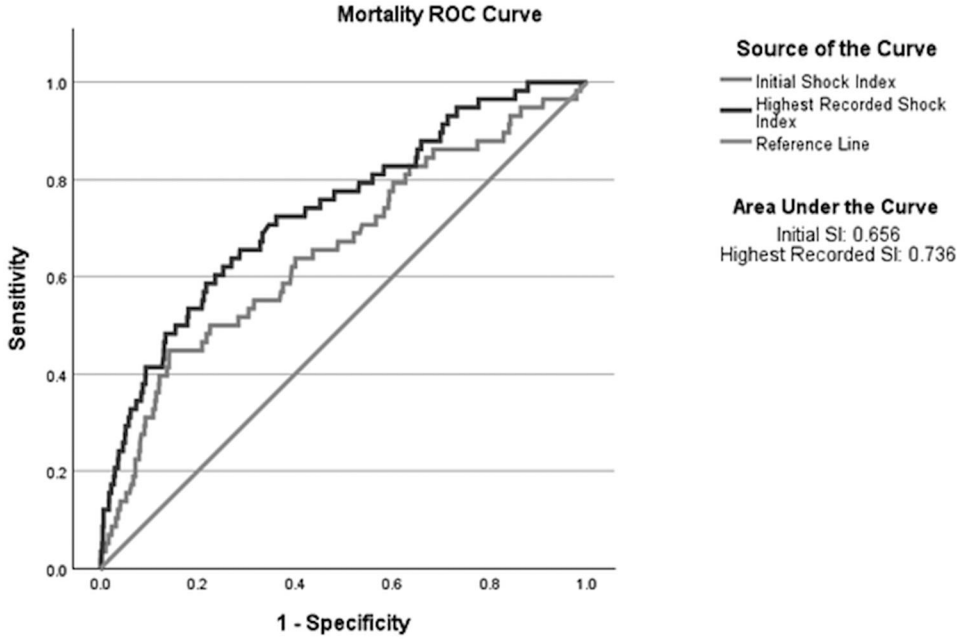


Figure 2. Mortality ROC curve. ROC showing the AUC for both Initial SI (0.656) and Highest Recorded SI (0.736). Both are between 0.65 and 0.75 indicating they provide *fair* utility as predictors of mortality.

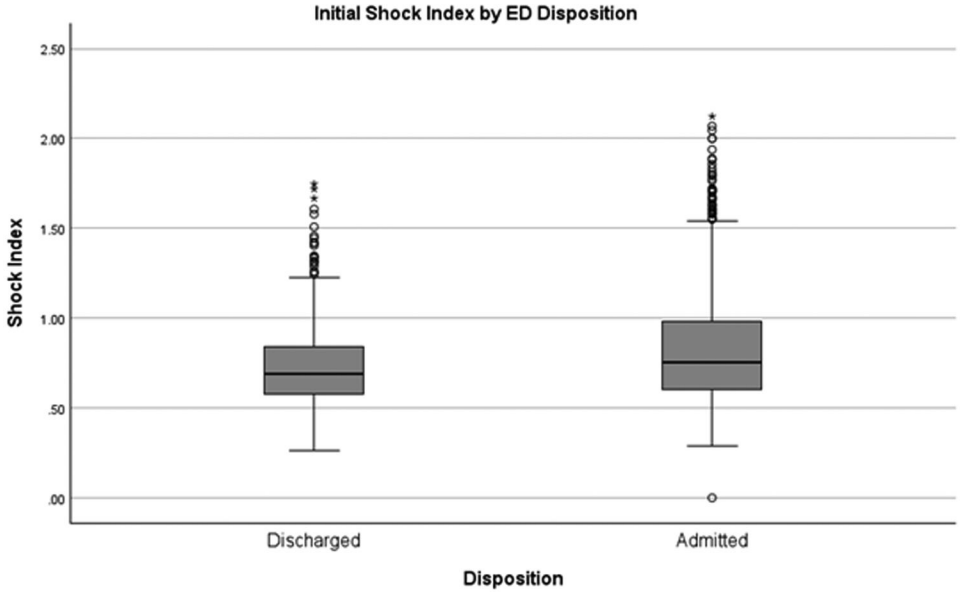


Figure 3. Initial shock index by ED disposition. Box plots showing the Initial SI mean and IQR for those who were admitted was not significantly higher than those who were discharged from the ED, though there were some outliers (represented by the circles) and extreme outliers (as represented by the asterisks).

hemorrhage. The observation that patients with higher SIs, particularly those with increasing values over time, had higher mortality rates suggests that SI could be a practical indicator of ongoing and severe blood loss. This is particularly relevant in the prehospital setting, where the rapid identification of severely ill patients is crucial for timely intervention.

Implications for Prehospital Care

Within the constrained parameters of prehospital care, marked by a scarcity of diagnostic resources, SI emerges as an indispensable stratification tool. Our findings advocate for a more integrated approach in prehospital protocols for patients with symptoms indicative of GI bleeding, where the SI's straightforward computation and its ability to convey critical information about the severity of hemorrhage become indispensable. The demonstrated association between higher SI values and an escalated mortality risk not only reiterates the necessity for EMS clinicians to leverage the SI in their triage processes but also highlights the importance of rapid response and comprehensive communication strategies. It facilitates a swift, yet informed, assessment, guiding EMS clinicians to prioritize patients with higher SI

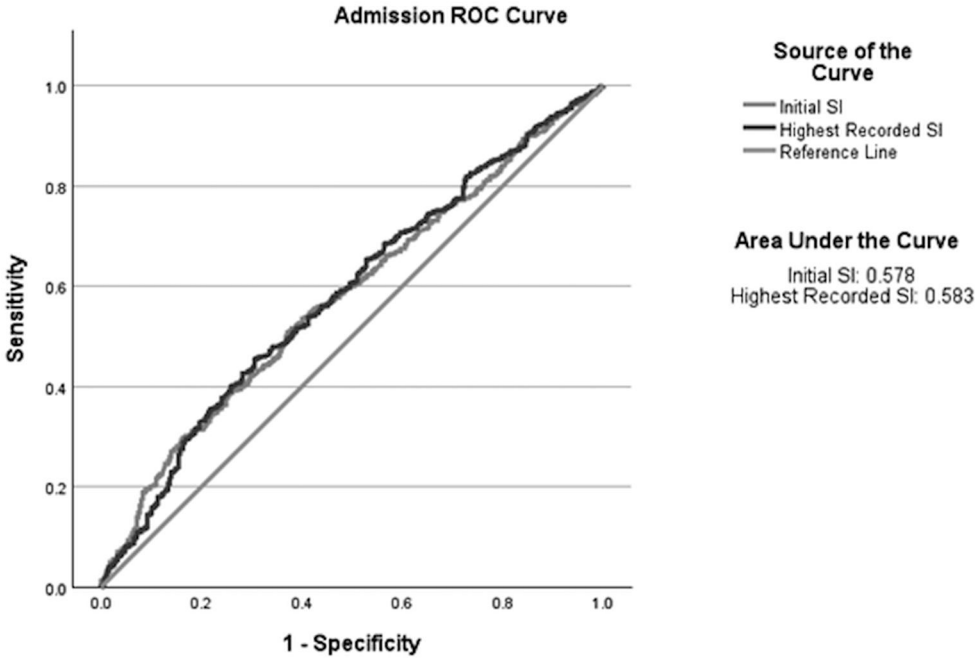


Figure 4. Admission ROC curve. ROC showing the AUC for both Initial SI (0.578) and Highest Recorded SI (0.583). Both are between 0.50 and 0.65 indicating they provide *poor* utility as predictors of admission,

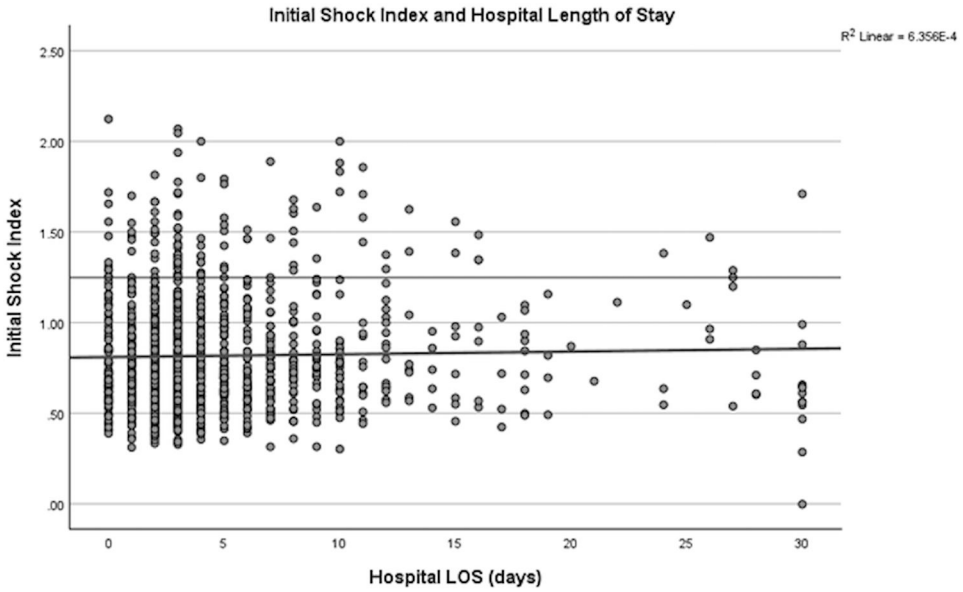


Figure 5. Initial shock index and hospital length of stay. Scatterplot of the relationship between the Initial SI of patients and their Hospital LOS, measured in days. The line represents the linear regression line (R^2 =0.0001), which shows there is a very weak correlation and suggests that the Initial SI explains a very small proportion of the variability in Hospital LOS.

readings for immediate transport. Such prioritization is crucial, not only for the expedited delivery to facilities equipped with comprehensive diagnostic and treatment capabilities, including endoscopic services but also for the initiation of early interventions that are paramount in stabilizing the patient's condition.

Considerations and Recommendations

While the SI demonstrates promise as a tool in the prehospital setting, it should be used as part of a broader clinical assessment. Its limited predictive value for hospital admission and the length of hospital stay, as indicated by our study, suggests that the SI should not be the sole factor guiding clinical decisions. It would be prudent for EMS clinicians to consider other clinical signs and symptoms, patient history, and the overall clinical context in conjunction with the SI.

Future Directions

Future research should focus on prospective studies to further validate the use of the SI in the prehospital setting, particularly in identifying patients with ongoing GI hemorrhage. Additionally, exploring the integration of the SI with other

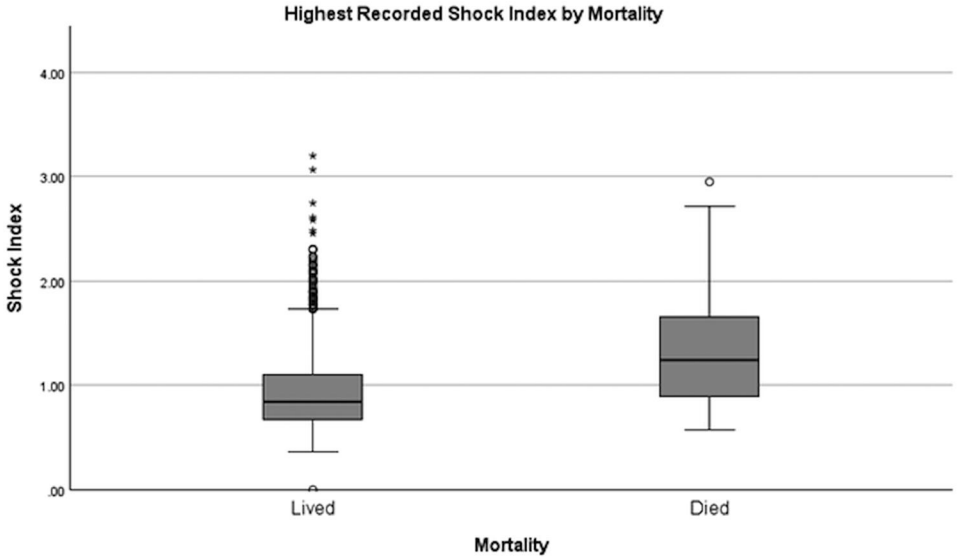


Figure 6. Highest recorded shock index by mortality. Box plots showing the Highest Recorded SI mean and IQR for those who lived was significantly lower than those who died, though there were some outliers (represented by the circles) and extreme outliers (as represented by the asterisks).

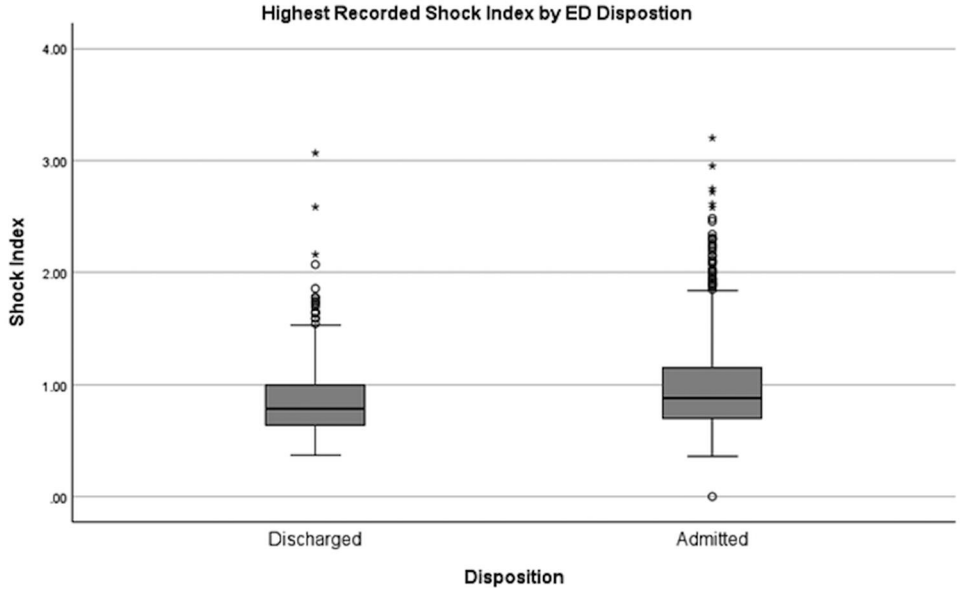


Figure 7. Highest recorded shock index by ED disposition. Box plots showing the Highest Recorded SI mean and IQR for those who were admitted was not significantly higher than those who were discharged from the ED, though there were some outliers (represented by the circles) and extreme outliers (as represented by the asterisks).

clinical parameters such as end-title CO2, mentation, and heaviness of bleeding could lead to the development of a more robust prehospital assessment tool for GI bleeding.

Limitations

While our study provides valuable insights into the utility of the SI in the prehospital assessment of patients with GI bleeding, several limitations need to be acknowledged:

- *Retrospective Design:* As a retrospective cohort study, our analysis is inherently limited by the nature of the data collected. There is a possibility of selection bias, information bias, and unmeasured confounders that could influence the study outcomes.
- *Data Completeness and Quality:* The study relied on prehospital care records, which may vary in terms of data completeness and accuracy. Variations in documentation practices among different EMS clinicians could affect the reliability of the SI calculations and subsequent analyses.
- *Generalizability:* Our findings are based on data from the ESO Data Collaborative, which, while comprehensive, may not be fully representative of all patient populations and EMS systems. The results might therefore not be generalizable to different regions or health care settings with varying protocols and patient demographics.
- *Single Measurement vs. Trend Analysis:* The study primarily focused on the initial and highest recorded SI values. Continuous monitoring and trend analysis of SI

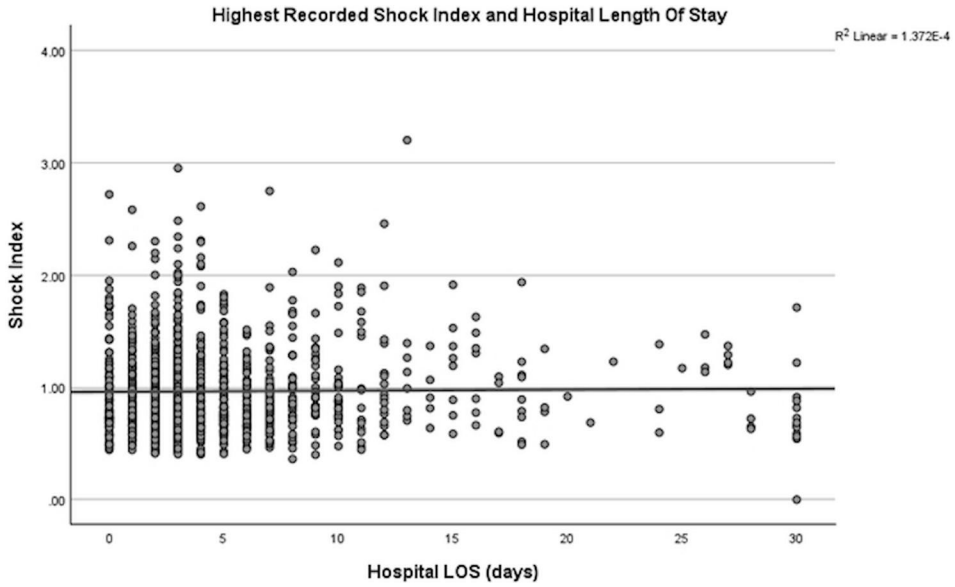


Figure 8. Highest recorded shock index and hospital length of stay. Scatterplot of the relationship between the Initial SI of patients and their Hospital LOS, measured in days. The line represents the linear regression line (R^2 =0.0001), which shows there is a very weak correlation and suggests that the Initial SI explains a very small proportion of the variability in Hospital LOS.

over time, which could provide more nuanced insights, were not explored due to the limitations of the dataset.

- *Absence of Additional Clinical Data:* The study did not account for other clinical factors such as the presence of comorbidities, medication use, or detailed history which could significantly influence the outcomes in patients with GI bleeding.
- *Lack of Comparative Analysis with Other Scoring Systems:* Our study did not compare SI with other established scoring systems used in hospital settings. Such a comparison could have provided a more comprehensive evaluation of the SI's relative efficacy.
- *Statistical Limitations:* The study's statistical methods, while robust, have inherent limitations. For example, the use of linear regression and ROC analysis provides specific insights but may not capture the complexity of clinical decision-making in prehospital care.

Conclusion

In summary, our study highlights the potential of the Shock Index as a tool for identifying patients at risk of severe outcomes from GI bleeding in the prehospital setting. Its ease of use and correlation with mortality risk make it a valuable addition to the triage process, especially in identifying patients with potentially ongoing hemorrhage.

Acknowledgments

The views and opinions expressed in this publication are strictly those of the author(s). They do not necessarily reflect the official policy or position of the Department of the Air Force, Department of Defense, or the United States Government. Similarly, the viewpoints presented in this paper are not affiliated with the University of Texas Health Science Center at San Antonio (UTHSCSA), the San Antonio Office of Medical Direction, or UT Health.

Disclosure statement

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