The Reverse Shock Index Multiplied by Glasgow Coma Scale Score for Prediction of In-hospital Adult Polytrauma Mortality Outcome in Emergency Department, Suez Canal University Hospitals

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ABSTRACT

Background: Trauma scoring systems anticipate mortality and enhance triage for resuscitation and medical involvement. The Reverse Shock Index multiplied by the Glasgow Coma Scale Score (rSIG), calculated as systolic blood pressure divided by heart rate, and multiplied by the GCS score, is a practical trauma scoring tool. It uses available physiological parameters and enables straightforward calculations, especially in busy emergency settings.

Objective: To assess the Reverse Shock Index (rSI) multiplied by Glasgow Coma Scale Score (rSIG) for anticipation of in-hospital mortality in comparison to Trauma and Injury Severity Score (TRISS) score in adult polytrauma patients.

Patients and methods: This cross-sectional observational study was conducted at Suez Canal University Hospitals in Ismailia and involved 104 adult polytrauma patients attending the Emergency Department.

The focus was to appraise the predictive value of rSIG for in-hospital mortality relative to the TRISS score.

Results: Non-survivors exhibited significantly lower mean scores for GCS, rSI, Revised Trauma Score (RTS), TRISS, and rSIG compared to survivors ($p<0.001$), while the average Injury Severity Score (ISS) was significantly higher in non-survivors relative to survivors ($p<0.05$). At a cutoff value of 14, rSIG predicted mortality in polytrauma patients, reaching a sensitivity of 94% and a specificity of 71% (AUC = 0.928).

Conclusion: The rSIG demonstrated significantly greater predictive accuracy for mortality across the entire study population. An rSIG value of <14 serves as a straightforward and timely indicator for evaluating mortality risk in adults with polytrauma.

Keyword: Trauma and Injury Severity Score, Systolic Blood Pressure, Triage, Revised Trauma Score.

INTRODUCTION

Trauma is the main source of morbidity rate and mortality, the sixth cause of the most common death worldwide [1]. In order to improve triage capacities and forecast mortality, trauma scoring systems were developed [2]. It's crucial to recognize trauma patients who are at a high potential of death so that vigorous resuscitation and appropriate medical intervention can begin [3].

The Trauma and Injury Severity Score (TRISS) is the greatest generally employed algorithm for predicting mortality outcomes in trauma patients. Nevertheless, its utilization in prehospital settings or emergency departments (ED) is constrained due to the requirement for comprehensive data concerning all injured organs, which may not be readily obtainable at the time of patient admission or may vary after admission [4].

The TRISS score integrates several parameters, counting the Revised Trauma Score (RTS), Injury Severity Score (ISS), age, and other relevant variables, to calculate the likelihood of survival in patients with both penetrating and blunt injuries [5]. This multifactorial approach enables a more nuanced assessment of trauma severity and associated mortality risk, yet the practical challenges of obtaining complete and timely data limit its immediate applicability in acute care situations. In trauma assessment, the severity of injuries sustained to various anatomical regions is systematically evaluated using the Abbreviated Injury Scale (AIS). This recognized scale is configured as a six-point ordinal system, with categories distinctly classified from minor injuries, assigned a score of 1, to injuries deemed unsurvivable, which are rated with the maximum score of 6. The AIS provides a standardized method for clinicians to categorize and communicate the extent of injuries, facilitating consistent evaluation across different cases and settings. To achieve a comprehensive measure of overall injury severity, researchers and healthcare providers utilize the Injury Severity Score (ISS). This objective metric is specifically calculated by summing the squares of the greatly AIS scores in the 3 utmost intensely impacted body areas. The ISS offers a quantitative assessment that encapsulates the severity of trauma sustained by a patient, allowing for better risk stratification and management tactics for trauma. By providing a numeric value that correlates with patient outcomes, the ISS serves as an invaluable tool in clinical research, aiding in determination of prognosis and guiding treatment decisions [5].

Additionally, the Revised Trauma Score (RTS) is applied as a physiological scoring system that further enhances the assessment of trauma severity. The RTS integrates vital clinical parameters, specifically the Glasgow Coma Scale (GCS), respiratory rate, and systolic blood pressure. Each component reflects critical aspects

Received: 01/09/2024
Accepted: 05/11/2024

of a patient's physiological status and response to injury, enabling healthcare professionals to evaluate the severity of trauma not only in terms of anatomical damage but also in relation to the overall physiological stability of the patient [6]. The integration of the RTS into trauma assessment protocols underscores the importance of understanding the complex interplay between anatomical injuries and physiological responses, thereby improving triage, resource allocation, and patient outcomes in emergency and trauma settings.

All earlier models used coded scoring systems that were difficult to learn and involved intricate computations and formulae that might not accurately represent patient circumstances in real time [7].

In-hospital mortality and ED disposition were predicted using a variety of trauma scoring systems, and it was discovered that TRISS was the most accurate predictor of death when compared to other scores [2].

A scoring method, the Reverse Shock Index multiplied by GCS score (rSIG, i.e., rSIG = Systolic blood pressure/Heart rate * GCS score), was proposed in retrospective multicenter research that was first conducted in Japan. They discovered that, when utilizing solely vital signs, the rSIG score is just as effective as the earlier prediction methods at identifying the probability of in-hospital death. To improve prediction accuracy, the rSIG score associates the hemodynamic (shock index) and neurologic state (GCS score). Systolic blood pressure (SBP), heart rate (HR), and GCS are readily available physiological data that the rSIG employs. It is easy to compute, particularly in busy emergency departments [8].

According to research by **Wu *et al.*** [4], trauma patients with head injuries had a rSIG cutoff point of 14.8 with 86.8% sensitivity and 70.7% specificity. rSIG is a useful method for predicting death in adult trauma patients suffering from head injuries, according to **Wan-Ting *et al.*** with 71% sensitivity and 75% specificity, the optimal rSIG cutoff point in their research sample was 14 [3]. Low rSIG is linked to a higher in-hospital death rate for adult trauma patients, according to a prospective multi-national and multi-center cohort research that used Pan-Asian Trauma facilities [9].

A retrospective study using data from the Taipei Tzu Chi trauma database **[10]** found that predictive accuracy of rSIG was higher than that of Shock Index, Modified Shock Index, and Age Shock Index in all patients (AUC, 0.710 vs. 0.495 vs. 0.527 vs. 0.598 respectively) and particularly for those suffering from moderate/severe traumatic brain injury (AUC, 0.625 vs. 0.450 vs. 0.476 vs. 0.529 respectively).

Our study aimed at appraising the utility of Reverse Shock Index multiplied by Glasgow Coma Scale Score (rSIG) as a rapid assessment tool within the Emergency Department for predicting in-hospital mortality among adult polytrauma patients at Suez Canal University Hospitals.

PATIENTS AND METHODS

This cross-sectional observational research was conducted on adult polytrauma patients who arrived at the emergency room of Suez Canal University Hospitals in Ismailia. Until the sample size was met, all consecutive patients encountered the following inclusion criteria.

Inclusion criteria:

1. Age > eighteen years old
2. Polytrauma patients (according to new Berlin definition):
   - AIS ≥ 3 for two or more different body areas.
   - Either one or more extra factors from the 5 physiological parameters: (age [≥70 years], coagulopathy [partial thromboplastin time ≥ 40 s or international normalised ratio ≥ 1.4], acidosis [base excess ≤ -6.0], unconsciousness [GCS score ≤ 8], and hypotension [SBP ≤ 90 mmHg] [11].

Exclusion criteria:

1. Missing hospital records.
2. Insufficient documentation to determine the outcome.

Procedure: A history was attained from the patients or members of their family.

Clinical examination: The primary survey (ABCDE) assessed each subject as follows: 1) Airway: Invasive, Patent, Maintained (non-invasive). 2) Breathing: Respiratory Rate (RR) and spontaneous breathing. 3) Circulation: blood pressure, pulse. 4) Glasgow coma score for disability. 5) Exposure: Examining patients from head to toe while protecting their privacy.

Laboratory investigations: Complete blood count (CBC), electrolytes, Arterial blood gas (ABG), Prothrombin Time Test (PTT), International Normalized Ratio (INR).

Score calculation: 1) Calculate rSIG= (SBP\ Heart Rate) * GCS [8]. 2) Calculate TRISS score. Probability of survival = $1/(1 + e^{-b})$ [5].

Follow up of the patients: 1) Monitor the patients and determine if they are admitted to the intensive care unit (ICU), discharged, or inwardly admitted. 2) To determine the duration of hospitalization. 3) Monitor vital signs, GCS, and rSIG score for 28 days prior to hospital release or death. 4) The mortality follow-up rates are 48 hours, 7 days, and 28 days.

In (Figure 1), 104 patients were included, after 48 hours 7 patients (7%) died and 97 (93%) admitted from them 15 patients (14%) discharged at 7 days. After 28 days, 15 patients (14%) died, 60 patients (58%) discharged, and 7 patients (7%) were admitted.

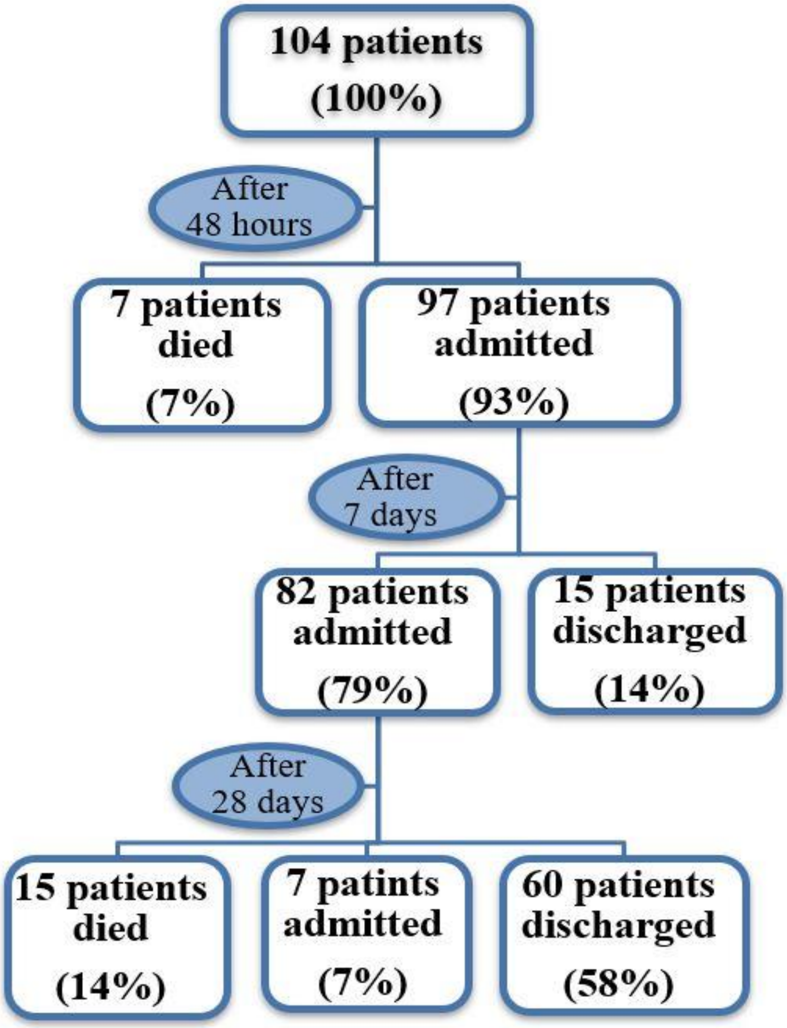

Figure (1): Flow chart of patients throughout the study.

Ethical consideration: Ethical approval for this research was granted by the Institutional Review Board of the Suez Canal University Faculty of Medicine. Prior to participation, an informed consent form explaining the goal as well as nature of the study was contracted by the patients or their family members. The study was performed in line with the ethical standards articulated in the Declaration of Helsinki, the World Medical Association's established guidelines governing research involving human subjects.

Statistical analysis: Data were entered into the computer statistical software after being coded. Version 25 of the Statistical Package for the Social Sciences (SPSS) was used for all statistical analyses. Tables and graphs were used to show the data. Quantitative data were displayed as mean ± standard deviation (SD), but qualitative data were displayed as numbers and percentages. Mann Whitney U test, Chi square test and Fisher exact test were tests used for statistical significance. $P < 0.05$ was considered significant.

RESULTS

As shown in (Table 1), the patients had length of hospital stay from 2 to 28 days, 51% were admitted in Intensive Care Unit and 21.2% died.

Table (1) Outcome results of the study patients.

		(n = 104)
Length of hospital stay (days)	**Mean ± SD**	14.21±3.45
	Range	2-28
Admission	**Intensive Care Unit**	53(51%)
	Inpatient	51(49%)
Fate	**Discharged**	82(78.8%)
	Death	22(21.2%)

In (Figure 2), reversed shock index multiplied by Glasgow coma scale score is increasing through days.

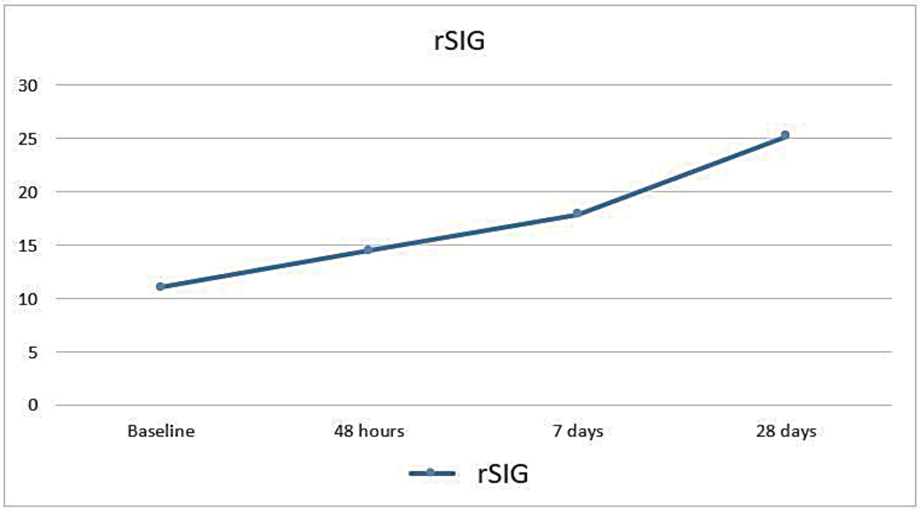

Figure (2): Serial Reverse Shock Index Multiplied by Glasgow Coma Scale Score (rSIG) measurements of the study patients.

Table 2 showed that there is no statistically significant difference for mean age of non survivors and survivors. Also, all non survivors had RTA, while survivors had RTA, FFH and stab in descending order with statistically significant difference. Non survivors had more frequent blunt trauma while survivors' mode of trauma was more with penetrating ones. Male showed predominance in both groups with more prevalence among survivors with no statistically significant difference.

Table (2): Comparison of basic demographic data among survivors and non survivors.

		Non-Survivors (n = 22)	Survivors (n = 82)	P-value
Age (years)	**Mean ± SD**	45.8±12.5	30.76±11.19	**0.37**
Sex	**Male**	15(68.2%)	66(80.5%)	**0.217**[2]
	Female	7(31.8%)	16(19.5%)	
Type of Accident	**FFH**	0(0%)	15(18.3%)	<**0.015***[3]
	RTA	22(100%)	59(72%)	
	Stab	0(0%)	8(9.7%)	
Type of injury	**Blunt**	15(68.2%)	38(46.3%)	0.069[2]
	Penetrating	7(31.8%)	44(53.7%)	

FFA – Fall From Height; RTA – Road Traffic Accident; 1. Mann Whitney U test; 2. Chi square test; 3. Fisher exact test; *Statistically significant.

The comparative analysis of injury scoring systems among survivors and non-survivors, as detailed in **Table 3**, yielded statistically significant disparities. Patients who did not survive exhibited substantially reduced mean values across multiple scoring metrics, including the Glasgow Coma Scale (GCS), Reverse Shock Index (rSI), Revised Trauma Score (RTS), Trauma and Injury Severity Score (TRISS), and Reverse Shock Index multiplied by Glasgow Coma Scale Score (rSIG). This suggests a strong association between lower scores on these scales and fatal outcomes. In contrast, the Injury Severity Score (ISS), an anatomically based scoring system, presented a significantly elevated mean value in non-survivors compared to survivors, reflecting a greater extent of anatomical injury in this group.

Table (3): Comparison of baseline scores measurement among survivors and non survivors.

	Non-Survivors (n = 22)	Survivors (n = 82)	P-value
GCS	4.68±0.48	12.45±2.64	<**0.001***
ISS	48±4.35	23.73±5.84	<**0.001***
rSI	0.61±0.16	1.04±0.31	<**0.001***
RTS	3.74±0.7	7.05±0.85	<**0.001***
TRISS	31.11±11.9	93.61±8.01	<**0.001***
rSIG	2.87±0.93	13.23±3.73	<**0.001***

GCS – Glasgow Coma Scale; ISS – Injury Severity Score; rSI – reverse Shock Index; rSIG – rSI multiplied by GCS score; RTS – Revised Trauma Score; TRISS – the Trauma and Injury Severity Score. Mann Whitney U test. *Statistically significant.

With respect to predictive capability, **Table 4** demonstrated that an rSIG threshold of 14 yielded a sensitivity of 94% and a specificity of 71% for foreseeing mortality in the entire trauma patient population. Furthermore, the ISS demonstrated a lower AUC of 0.814 compared to the RTS and TRISS, which had AUCs of 0.887 and 0.881, respectively, indicating superior discriminatory capacity of the latter two scoring systems. Negative predictive value of rSIG was higher than that of TRISS (92.2% vs 89% respectively) while Positive Predictive Value of rSIG was lower than that of TRISS (76.4% vs 82.% respectively).

Table (4): Validity of Injury Severity Score, Revised Trauma Score, Trauma and Injury Severity Score and reverse Shock Index multiplied by Glasgow Coma Scale Score in predicting the mortality of patients with all types of traumas.

Variable	AUC	Cutoff	Sensitivity	Specificity	PPV	NPV	Accuracy
ISS	0.814	28	88%	64%	71%	78%	76%
RTS	0.887	7.5	91%	77%	79.8%	89.5%	84%
TRISS	0.881	97	90%	81%	82.6%	89%	85.5%
rSIG	0.928	14	94%	71%	76.4%	92.2%	82.5%

ISS – Injury Severity Score; rSIG – reverse Shock Index multiplied by Glasco Coma Scale score; RTS – Revised Trauma Score; TRISS – Trauma and Injury Severity Score. PPV: Positive Predictive Value. NPV: Negative Predictive Value. AUC: Area Under the Curve.

DISCUSSION

The mainstream of injury-related deaths happens in low- and middle-income countries (LMICs) because of a deficiency of human resources and technology for trauma care. When triaging patients in packed emergency rooms or during mass casualty occurrences, it is critical to identify wounded individuals who are in imminent danger of dying soon or who have a very low chance of dying. Additionally, building health care systems in LMICs requires quality improvement (QI) in trauma care systems, and QI necessitates impartial assessment of consequences with risk adjustment [4].

In the management of trauma patients, precise prognostication of mortality risk remains vital in effective triage and intervention. The Trauma and Injury Severity Score (TRISS) continues to be a prevalent predictive tool utilized in trauma care for estimating the probability of survival [12].

The TRISS calculation incorporates several key variables: patient age, a demographic factor influencing physiological reserve; the Injury Severity Score (ISS), a composite measure of anatomical injury severity; and the Revised Trauma Score (RTS), a physiological scoring system reflecting the patient's immediate physiological status upon presentation. Furthermore, the TRISS methodology differentiates between penetrating and blunt mechanisms of injury by applying specific weighting coefficients to account for the distinct patterns of injury associated with each mechanism. The ISS is derived from the Abbreviated Injury Scale (AIS), which assigns numerical grades to injuries based on their anatomical location and severity. To calculate the ISS, the squares of the AIS scores for the three most severely injured body regions, selected from six predefined anatomical regions (head and neck, face, thorax, abdomen, extremities, and external), are summed [13].

The Revised Trauma Score (RTS) is derived from a weighted combination of the patient's initial Glasgow Coma Scale (GCS) score, representing neurological status, and two key physiological parameters: systolic blood pressure (SBP) and respiratory rate (RR). These variables are encoded as weighted values and subsequently aggregated to generate the RTS. Despite its demonstrated accuracy in predicting mortality outcomes, the application of the Trauma and Injury Severity Score (TRISS) in the prehospital setting or upon first admission to the emergency department (ED) is constrained. This limitation arises from the TRISS algorithm's reliance on comprehensive anatomical injury data encompassing all affected organ systems. Such detailed information is frequently unavailable at the time of admission and may also be subject to dynamic change following initial assessment [14].

The 28-day mortality rate observed in this study was 21.2% (22 out of 104 patients) which exceeds the 30-day mortality rate of 13.5% reported in a study conducted in Finland [15]. Notably, Finland possesses a well-developed healthcare infrastructure, experiences a relatively high incidence of traumatic brain injury (TBI), and has a comparatively low prevalence of penetrating trauma. The mean age of non-survivors in this research had no statistically significant difference than that of survivors (p=0.37).

Given that older people often have higher SBP and less sympathetic-responsive HR, another study found that age did affect mortality prediction. This might result in a rise in false-negative SBP readings by means of people age, even for SI or rSI [16]. It has been shown that in all ED patients, the correlation between a SI of ≥1 and the 30-day mortality risk is weakened by age [17]. Additionally, it has been observed that rSIG has the best predictive accuracy when it comes to predicting survival in younger age groups (not more than 55 years old) [8].

In this study, we showed that the rSIG can predict the likelihood of death for all trauma patients with a predictive accuracy (AUC = 0.928) of 94%, 71% specificity, and 94% sensitivity at a threshold value of 14. RTS (AUC = 0.887) and TRISS (AUC = 0.881) both indicated higher predictive accuracy than ISS (AUC = 0.814).

In their study, **Chen *et al.*** [18] identified the Reverse Shock Index multiplied by Glasgow Coma Scale Score (rSIG) threshold of 18 as a critical cutoff for predicting both short-term death as well as unfavorable functional outcomes in trauma patients. The establishment of this threshold is significant as it provides clinicians with a quantitative measure to assess the magnitude of injury and its potential influence on patient prognosis.

Another study demonstrated rSIG's predictive capacity for major transfusion, exhibiting the highest area under the curve (AUC = 0.842). Furthermore, rSIG achieved the highest AUC values for prediction of 24-hour mortality (AUC = 0.826), in-hospital mortality (AUC = 0.812), and coagulopathy (0.769). The sensitivity and specificity of rSIG for predicting massive transfusion have been reported as 0.79 and 0.77, respectively [19].

Conversely, other research indicated that the Revised Trauma Score (RTS) exhibited significantly superior predictive accuracy compared to rSIG in patients with isolated head injuries (AUC = 0.85 vs. AUC = 0.82, p = 0.02) and in the overall trauma population (AUC = 0.85 vs. AUC = 0.83, p = 0.02). Nevertheless, no statistically significant variance was reported in the predictive performance of rSIG in addition to RTS in patients without head injuries (AUC = 0.83 vs. AUC = 0.83, p = 0.97, respectively) [4].

Another study suggests the Reverse Shock Index multiplied by Glasgow Coma Scale Score (rSIG) can be utilized to expect mortality in adults with intense trauma and concomitant head injury. In this study, the optimal rSIG cutoff threshold for the research population was determined to be 14, likely due to the significantly lower Glasgow Coma Scale (GCS) score observed in the mortality group (6.28 ± 4.25) compared to the survival group (12.70 ± 5.19) [3].

Recent research findings have indicated that the Reverse Shock Index multiplied by Glasgow Coma Scale Score (rSIG) shows markedly enhanced predictive capability regarding mortality among polytrauma patients when compared to traditional assessment tools such as the Shock Index (SI), Modified Shock Index (MSI), and Age Shock Index. This assertion is substantiated by correlating the area under the curve (AUC) values derived from receiver operating characteristic (ROC) analysis, which serves as a standard method for evaluating the diagnostic performance of clinical models. Specifically, the AUC for rSIG was reported at 0.710, suggesting that it possesses a strong ability to accurately predict mortality risk in polytrauma scenarios. In contrast, the Shock Index (SI) demonstrated a significantly lower predictive performance, with an AUC value of only 0.495. Likewise, the Modified Shock Index (MSI) displayed an AUC of 0.527, and the Age Shock Index yielded an AUC of 0.598. These values highlight a clear distinction in the effectiveness of rSIG as a predictive tool. The superior performance of rSIG can be attributed to its comprehensive approach, which integrates multiple physiological parameters, thereby providing a further nuanced assessment of a patient's hemodynamic status and overall stability. This enhanced predictive capability of rSIG underscores its potential utility in clinical settings, offering significant implications for triaging polytrauma patients and informing treatment decisions. As a result, the adoption of rSIG in emergency and trauma medicine could lead to improved patient outcomes through more accurate risk stratification and timely interventions [10].

According to a systematic analysis, SI is the lowest score for predicting trauma patients' death, whereas TRISS is the finest among a variety of trauma ratings. In addition to the physiological factors (RTS), TRISS predicts the mortality result by using other data, including age, anatomical characteristics (ISS), and method (penetrating or blunt). Consequently, it is not unexpected that TRISS outperformed rSIG and RTS, which only depend upon the alterations in physiology of patients with trauma, in terms of prediction accuracy. The mortality result had a substantial correlation with the injury mechanism and ISS [7].

In the present study, the Injury Severity Score (ISS) demonstrated the lowest predictive accuracy compared to the other three models evaluated. This finding is consistent with the expectation that incorporating additional physiological variables, as in the Reverse Shock Index multiplied by Glasgow Coma Scale Score (rSIG) and Revised Trauma Score (RTS), would enhance predictive performance relative to a purely anatomical scoring system like the ISS.

Conversely, another study reported that rSIG exhibited significantly lower predictive accuracy than RTS for both patients with isolated head injuries and the overall trauma population [4].

However, rSIG has also been shown to outperform the Shock Index (SI) and Modified Shock Index (MSI) in predicting outcomes for patients with multiple trauma injuries, achieving an area under the curve (AUC) of 0.806 (95% CI: 0.737–0.876). Sensitivity analysis within the multi-trauma injury group further revealed that rSIG more accurately predicted mortality in the subgroup with mixed traumatic brain injury (TBI) compared to SI and MSI, with an AUC of 0.792 (95% CI: 0.700–0.883). Falls, a frequent mechanism of injury, can result in both TBI and traumatic spinal cord injury (tSCI). Spinal cord injury can compromise hemodynamic stability due to spinal shock, a condition characterized by hypotension despite a normal heart rate [10].

Research conducted by **Jung *et al.*** [9] has demonstrated a correlation between lower Reverse Shock Index multiplied by Glascow Coma Scale Score(rSIG) scores and increased in-hospital mortality among adult trauma patients. However, this study also indicated a significantly improved mortality prognosis for younger patients specifically with traumatic brain injury (TBI). Furthermore, a more recent investigation [20] suggests that rSIG serves as a practical and effective point-of-care tool for predicting the need for emergent interventions during the initial management of trauma patients.

CONCLUSION

According to this study, rSIG outperformed other scores in terms of death prediction accuracy throughout the whole population under consideration. **In busy emergency departments, the rSIG is simple to administer and effective. A quick and easy method to predict death in adult patients with polytrauma is the rSIG.** Additionally, it could help doctors properly use medical resources and appropriately dispose of patients. For adult polytrauma patients with a score of ≥14, mortality could be ruled out.

Declaration of conflicting interests: NIL.
Funding: NIL.

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