REUE | Original Article

Validity of the Reverse Shock Index multiplied by the Glasgow Coma Scale score for determining mortality in patients with severe trauma in the prehospital environment

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BACKGROUND. Although various scales are available to predict mortality and prognosis for patients with severe trauma, they are difficult to apply in prehospital settings. The Reverse Shock Index multiplied by the Glasgow Coma Scale score (rSIG) has been reported to predict mortality in severe trauma.

OBJECTIVES. The main objective was to study whether the rSIG was a better prehospital predictor of mortality in severe trauma than the Shock Index (SI), the Age SI, or the Revised Trauma Score (RTS). The secondary aims were to determine the predictive power of hemodynamic and analytic variables and to analyze the metabolic and hemodynamic status of patients with a low rSIG.

MATERIAL AND METHODS. Retrospective observational study of a cohort of patients over the age of 16 years who were attended by an out-of-hospital emergency service for severe trauma between June 2021 and December 2023. We calculated the areas under the receiver operating characteristic curves (AUCs) for the rSIG and the other indexes as predictors of 7-day mortality. We also analyzed the AUCs for analytic parameters and vital constants.

RESULTS. The cases of 619 patients were studied. The mean patient age was 42.1 years, 79.8% were male, and overall 7-day mortality was 10.3%. Only the rSIG (AUC, 0.734; 95% CI, 0.807-0.660; $P < .001$) and the RTS (AUC, 0.734, 95% CI, 0.807-0.660; $P < .001$) predicted mortality. The rSIG cut point of 12.7 had a sensitivity of 70.3% and a specificity of 69.7% for 7-day mortality.

CONCLUSIONS. Even considering the limitations of this study, the rSIG seems to be a useful prehospital predictor of mortality in severe trauma attended out-of-hospital and may be comparable to other internationally validated scales such as the RTS. A value of less than 12.7 on the rSIG should possibly be considered a predictor of potentially high-risk.

Keywords: Risk assessment. Trauma severity indices. Glasgow Coma Scale. Prehospital emergency care. Mortality.

Validez del rSIG (Reverse Shock Index multiplied by Glasgow) *para determinación de mortalidad en el paciente con enfermedad traumática grave en el entorno prehospitalario*

INTRODUCCIÓN. Diversas escalas tratan de determinar la mortalidad y pronóstico de los pacientes con enfermedad traumática grave (ETG). Sin embargo, éstas son de difícil aplicación en el medio prehospitalario. El Índice de *Shock* Reverso por Glasgow (rSIG) cuenta con evidencia que lo respalda como predictor de mortalidad en los pacientes con ETG.

OBJETIVO. Evaluar si el rSIG aumenta la predicción de mortalidad en pacientes ETG en el entorno prehospitalario, con respecto a Índice de *Shock* (IS), IS asociado a la edad (SIA) y *Revised Trauma Score* (RTS).

MATERIAL Y MÉTODOS. Estudio observacional retrospectivo de una cohorte de pacientes mayores de 16 años atendidos por un servicio de emergencias prehospitalario con diagnóstico de ETG, entre junio 2021 y diciembre 2023. Se calculó el AUC (área bajo la curva) para mortalidad a los 7 días del rSGI, IS, SIA y RTS. Se analizaron las AUROC de parámetros analíticos y constantes vitales.

RESULTADOS. Se analizaron 619 pacientes: la media de edad de 42,1 años con un 79,8% de varones. La mortalidad global a los 7 días fue: 10,3%. Solamente rSIG (AUC 0,734, IC 95%: 0,807-0,660, $p < 0{,}001$) y RTS (AUC 0,734, IC 95%: 0,807-0,660, $p < 0{,}001$) se asociaron estadísticamente con mortalidad. El rSIG, con un punto de corte de 12,7, mostró sensibilidad del 70,3% y especificidad del 69,7% para mortalidad los primeros 7 días.

CONCLUSIONES. En el medio prehospitalario, el rSIG puede ser un índice pronóstico fiable para predecir la mortalidad en ETG. Los pacientes con valor de rSIG < 12,7 podrían ser considerados inicialmente como potencialmente graves.

Palabras clave: Escalas pronósticas de severidad de Trauma. Escala de Coma de Glasgow. Medicina Prehospitalaria. Mortalidad.

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Introduction

Severe traumatic disease (STD) is one of the leading causes of morbidity and mortality worldwide. Its main trigger is hemorrhage—one of the preventable causes. Early detection and treatment are essential for a favorable outcome.[1]

Currently, there are numerous predictive severity scales designed to determine mortality and prognosis in patients with STD. Among them are the Injury Severity Score (ISS), Revised Trauma Score (RTS), New Injury Severity Score (NISS), and the Trauma Injury Severity Score (TRISS), the latter being the most reliable in predicting mortality.[2] However, their application requires imaging tests and complex mathematical calculations, which limits their use in prehospital settings.[3]

Therefore, it would be highly beneficial to have a reliable, quick, and simple tool to determine the severity and prognosis of these patients.

The Shock Index (SI) was developed as an alternative to conventional scales, as it is fast, simple, and easy to reproduce at the bedside. Numerous studies have demonstrated its reliability in predicting mortality, showing greater accuracy than isolated vital signs.[4] However, it has some limitations in certain subgroups where its predictive capacity is reduced.[5,6]

The Reverse Shock Index by Glasgow (rSIG) is a recent scale that evaluates both hemodynamic and neurological components. There is evidence supporting its role as a predictor of mortality in patients with STD,[6-12] and several studies have demonstrated its ability to predict the need for massive transfusion,[7] as well as its usefulness in patients with traumatic brain injury (TBI).[8]

However, all studies conducted so far have been based on the hospital setting, creating the need to assess the applicability of this scale in the prehospital environment, in the care of patients with STD.

The main endpoint of this study was to determine the usefulness of rSIG in predicting mortality in patients with STD, comparing it with classic prognostic indices and scales (SI, RSI, age-adjusted SI – ASI –, and RTS). Secondary endpoints included determining the predictive capacity of hemodynamic and analytical variables, as well as characterizing the metabolic and hemodynamic status of patients with altered rSIG values.

Material and methods

We conducted a retrospective observational study on a cohort of patients older than 16 years treated by the prehospital emergency service SAMUR–Protección Civil of Madrid with a diagnosis of severe trauma (ISS > 15) from June 2021 through December 2023.

From an initial database of 729 consecutive patients diagnosed with severe trauma, after applying the exclusion criteria [pediatric patients (< 16 years), burns, cardiac arrest (CA) upon arrival of the advanced life support (ALS) unit, comorbidities preventing a reliable Glasgow Coma Scale (GCS) assessment, and missing data], a final sample of 619 patients was obtained (Figure 1).

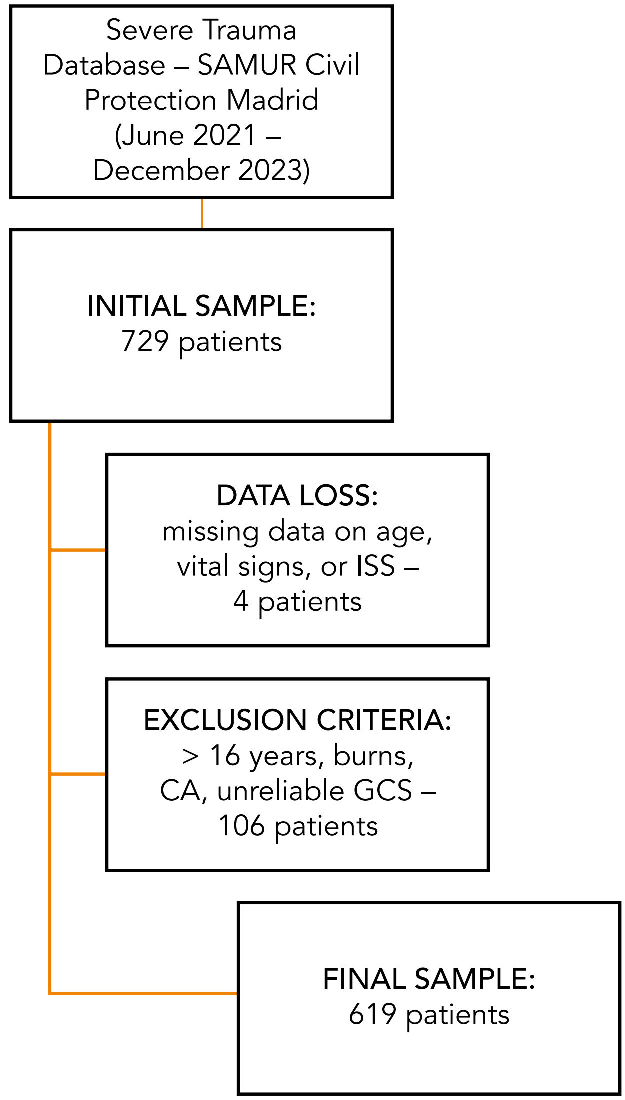

Figure 1. Flowchart of patient selection.
CA: cardiac arrest; GCS: Glasgow Coma Scale.

The number of patients included met the minimum requirements for statistical significance, since, based on the population studied, with a 95% confidence interval (CI) and a 5% margin of error, a minimum sample size of 385 patients was required.

Collected variables included demographics (sex, age), mechanism of injury, type of trauma, vital signs (respiratory rate [RR], heart rate [HR], initial and final systolic blood pressure [SBP]), GCS score, and analytical parameters: pH, base excess (BE), lactate, calcium, and hemoglobin. Different indices and scales were also considered as independent variables for univariate analysis. The primary endpoint variable was 7-day mortality.

The following index values were calculated: SI = HR/SBP; RSI = SBP/HR; ASI = SI × age; rSIG = (SBP/HR) × GCS; and RTS = (0.9368 × GCS) + (0.7326 × SBP) + (0.2908 × RR). To evaluate the association of each index or scale with mortality, ROC curve analyses were performed, assessing the area under the curve (AUC) for each parameter for 7-day hospital

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Table 1. Vital signs and Glasgow Coma Scale scores in the series

Vital signs	Mean (SD)	AUC	*P*
Respiratory rate	17.24 (5.50)	0.664	.001
Heart rate	95.39 (26.78)	0.551	.046
Initial SBP	121.64 (31.70)	0.488	.050
Final SBP	124.47 (57.64)	0.480	.046
GCS	11.70 (4.4)	0.808	.001

AUC: area under the curve; SD: standard deviation; SBP: systolic blood pressure; GCS: Glasgow Coma Scale.

mortality. The AUC of analytical parameters and vital signs was also assessed for the same dependent variable.

This study was approved by the SAMUR–PC Research Ethics Committee, ensuring proper anonymization of participants. Data were analyzed using SPSS v22.

Results

The mean age of the 619 patients was 42.1 years (SD, 18.5), of whom 494 were men (79.8%). The most frequent type of trauma was blunt trauma in 493 patients (79.7%), with the remainder corresponding to penetrating trauma.

The most common injury mechanism was traffic accidents, affecting 265 patients (42.8%), including 86 pedestrian collisions (13.9%). The second most frequent mechanism was falls from height (106 patients, 17.1%), followed by run-over incidents (23 cases, 3.7%). A total of 36% (36%) of patients presented associated TBI, of which 55% were isolated TBI without other traumatic injuries. The overall 7-day mortality was 10.3% (64 patients).

Vital signs and GCS data are shown in Table 1.

Regarding the association with mortality, GCS stood out as the best predictor, with AUC, 0.808 (95% CI, 0.867–0.749; $P < .001$). Respiratory rate also showed a statistically significant association, with AUC, 0.664 (95% CI, 0.743–0.586; $P < .001$) (Table 1). The comparative ROC curves of all vital signs are shown in Figure 1. The cutoff point for mortality prediction was 8.5 for GCS and 14.5 for RR.

The analytical parameters showed greater deviation from normal values than vital signs, mainly due to metabolic markers pH, BE, and lactate (Table 2). In the association with mortality, pH and hemoglobin showed clear statistical significance, with AUC for pH = 0.601 (95% CI, 0.687–0.516; $P = .0012$) and hemoglobin = 0.657 (95% CI, 0.728–0.587; $P < .001$) (Table 2). The remaining results are shown as ROC curves in Figure 2. The cutoff values were pH = 7.30 and hemoglobin = 15.05 g/dL.

Prognostic indices and scales are presented in Table 3. The AUC values were as follows: SI: 0.544 (95% CI, 0.638–0.450; $P = .255$); ASI: 0.559 (95% CI, 0.642–0.476; $P = .125$); RTS: 0.785 (95% CI, 0.850–0.720; $P < .001$); RSI: 0.527 (95% CI, 0.620–0.433; $P = .484$); and rSIG: 0.734 (95% CI, 0.807–0.660; $P < .001$) Only RTS and rSIG reached statistically significant values (Table 3, Figure 3).

The rSIG cutoff value was 12.7, with 70.3% sensitivity and 69% specificity (95% CI). Based on this cutoff, the mean values of both vital and analytical parameters were analyzed (Figure 6). Notably, the mean GCS was 7.49 (SD, 4.68), alongside a decrease in SBP values.

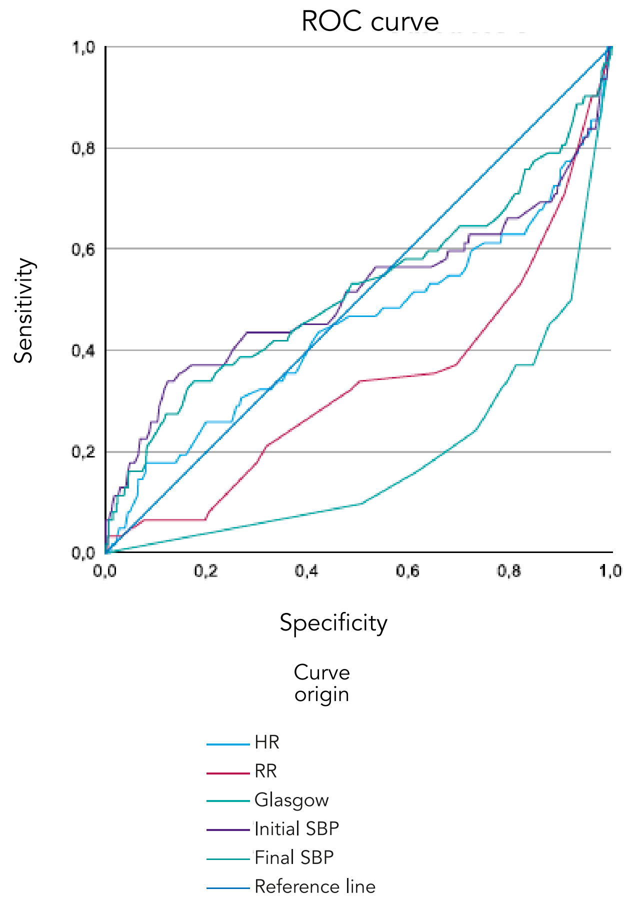

Figure 2. ROC curve of vital signs.
HR: heart rate; RR: respiratory rate; SBP: systolic blood pressure.

Regarding metabolic parameters, there was a clear alteration in nearly all values, highlighting more severe acidosis (pH = 7.26, SD, 0.13), decreased hemoglobin (14.79 g/dL, SD, 2.21), and signs of hypoperfusion — BE: –4.65 mmol/L (SD, 5.69); lactate: 5.82 mmol/L (SD, 4.67) (Figure 6).

Discussion

The main limitation of anatomical assessment scales lies in their dependence on radiological tests, complex calculations, or other difficult-to-memorize data, which makes their application in the prehospital setting practically nonexistent.

To overcome this limitation, the SI was developed. First described by Allgower and Burri in 1967,[13] it was established as a rapid and reliable indicator for the early detection of shock.[14] This index allows identification of potentially severe patients even when vital signs appear "stable," since SBP is a late indicator of shock. The SI is easily calculated without additional information or equipment and has been used to identify the risk of mortality and the need for massive transfusion,[15] even in the presence of severe TBI.[16]

Despite this, our study did not find statistical significance when using SI as a predictor of mortality in STD. It showed an AUC of 0.544, very similar to classical parame-

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Table 2. Analytical data (point-of-care determination) of the series

Analytical values	Mean (SD)	AUC	*P*
pH	7.30 (0.17)	0.601	.012
BE (mmol/L)	–3.4 mmol/l (5.41)	0.551	.203
Lactate (mmol/L)	5.93 (18.06)	0.445	.167
Calcium (mmol/L)	1.33 (4.48)	0.471	.466
Hemoglobin (g/dL)	17.83 (61.73)	0.657	.001

AUC: area under the curve; SD: standard deviation; BE: base excess.

ters such as HR and SBP (0.449 and 0.512, respectively). This contrasts with previous literature, as the SI is widely validated. The low predictive capacity observed in our study may be explained by several factors: on one hand, patients in CA upon arrival of ALS were excluded; on the other hand, a single 7-day cutoff point was used, and overall in-hospital mortality was not assessed. These factors may have contributed to the loss of statistical significance.

The SI has several important limitations, one of which is age. In elderly patients, SI may underestimate the severity of underlying shock, as these patients tend to have a lower sympathetic response and higher baseline SBP.[17] Some studies have shown that in elderly patients, an SI > 1 is associated with worse 30-day mortality compared with younger patients[18].

To address this issue, Zarzaur *et al.*[4,5] developed the ASI, which performs better in patients older than 55 years. McNab *et al.*[19] corroborated these findings, though with a different cutoff point. In their work, SI correlated well with the need for blood products, mechanical ventilation, and ICU or hospital stay in patients under 60 years of age. For those above this threshold, SI lost significance and correlated less with these outcomes.

In our study, adding age to the SI slightly increased its predictive capacity, but not enough to reach statistical significance. This may be explained by the relatively young mean age (42 years) of our patients—well below the thresholds indicated in former studies.

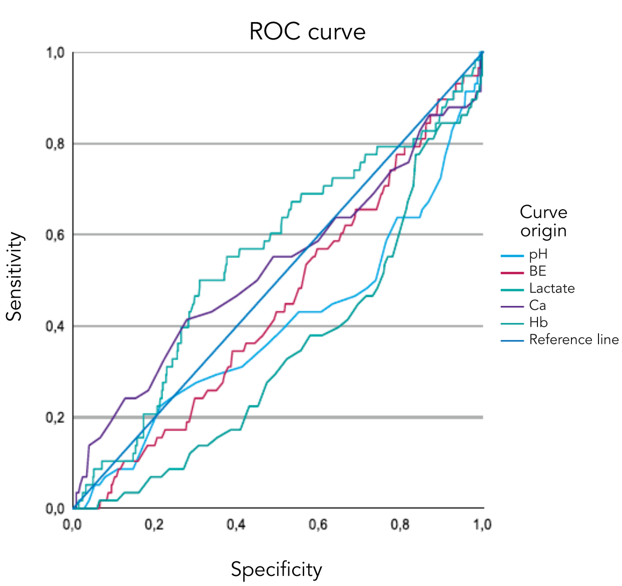

Figure 3. ROC curve of analytical parameters.
BE: base excess; Ca: calcium; Hb: hemoglobin.

Table 3. Calculation of prognostic indices and scales in the series

Prognostic index/scale	Mean (SD)	AUC	*P*
SI	0.85 (0.37)	0.544	.255
ASI	1.40 (0.64)	0.559	.125
RSI	34.9 (22.1)	0.527	.484
RTS	6.91 (1.38)	0.785	.001
rSIG	16.08 (8.81)	0.734	.001

AUC: area under the curve; SD: standard deviation; SI: Shock Index; ASI: Age-adjusted Shock Index; rSI: Reverse Shock Index; RTS: Revised Trauma Score; rSIG: Reverse Shock Index by Glasgow.

Another important limitation of the SI is TBI. In its most severe form, TBI can cause elevated intracranial pressure (ICP), leading to clinical signs, such as bradycardia and hypertension. This phenomenon, known as Cushing's triad, affects the performance and accuracy of SI in predicting mortality.[20,21] Furthermore, TBI associated with hemorrhage can alter autonomic responses due to blood loss or impaired vascular tone regulation. In these cases, SI may misinterpret the shock state.[22,23]

This aspect is particularly relevant in our study, as 36% of patients presented with associated TBI. The GCS is the best prognostic scale for patients with TBI, outperforming vital signs, age, and even overall trauma severity.[24,25] Our results support this finding: GCS was the independent variable with the greatest predictive power for mortality (AUC, 0.804). Using a cutoff point of 8.5, mortality increased significantly in patients with lower values.

Regarding the Reverse Shock Index (rSI), defined as the SBP/HR ratio, literature[26,27] suggests it is preferable to the traditional SI, as it aligns more closely with the physiological concept of shock, where a hemodynamically unstable patient has SBP lower than HR, not vice versa. In other words, rSI < 1 indicates shock. Since most studies reported superior performance of rSI over SI, we included it in our analysis. Nevertheless, the data were not positive, with an AUC of 0.527, lacking statistical significance.

The rSIG was first introduced by Kimura and Tanaka in 2018,[6] who analyzed 168,517 patients from 256 hospitals in Japan between 2006 and 2015. Their goal was to identify a better predictor than SI for mortality and the need for blood transfusion within the first 24 hours.

After analyzing various modifications of SI, they identified rSIG as a reliable tool for assessing mortality risk in patients with STD, showing an AUC of 0.901 for in-hospital mortality. Wu *et al.*[10] externally validated rSIG in a later study, confirming that rSIG had greater predictive accuracy for mortality than SI in trauma patients (AUC, 0.83).

Wan *et al.*[8] recently used rSIG to evaluate in-hospital mortality in patients with STD and TBI, finding that rSIG also effectively predicted mortality in this subgroup.

In our study, the AUC of rSIG for in-hospital mortality was 0.734, and its predictive value for mortality was higher than SI and ASI, and very similar to RTS. With a cutoff value of 12.7, rSIG predicted 7-day mortality in patients with STD with 70.3% sensitivity and 69.7% specificity. These findings are consistent with previous studies showing rSIG as a useful predictor of mortality in trauma patients.

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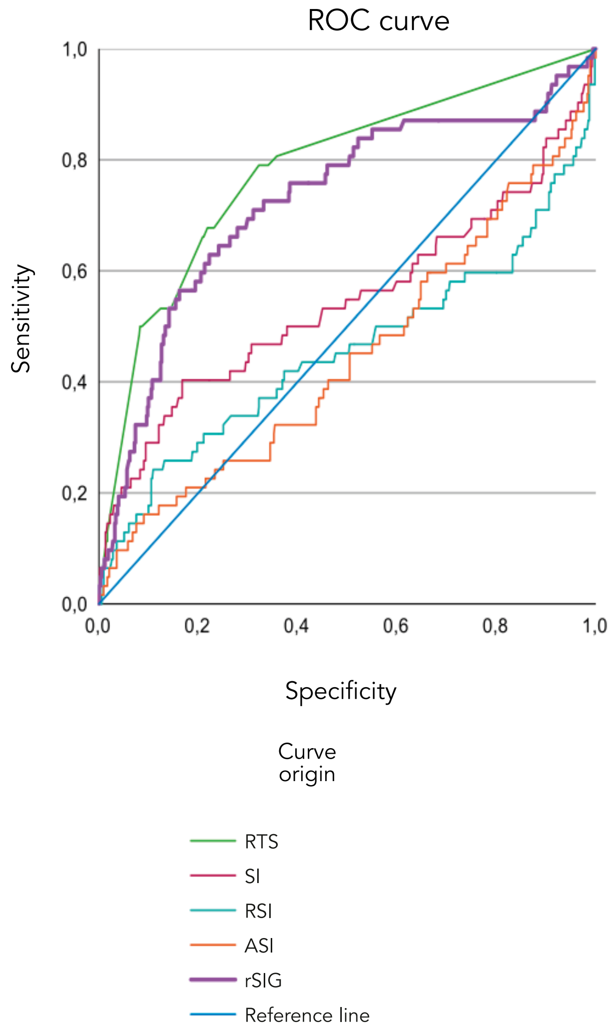

Figure 4. ROC curves of prognostic indices and scales.
SI: Shock Index; ASI: Age-adjusted Shock Index; rSI: Reverse Shock Index; RTS: Revised Trauma Score; rSIG: Reverse Shock Index by Glasgow.

Of note, in our study, patients with rSIG below the cutoff—even when presenting with hemodynamic values considered normal—had lower GCS values. Analytically, these patients also showed significant lactate and BE alterations, indicative of hypoperfusion. This finding opens the door for future studies to explore rSIG as an early marker for resuscitation needs, as well as for the administration of vasoactive or antihemorrhagic agents.

Table 4. Values of vital signs and analytical parameters in patients with rSIG < 12.7

	Mean	Standard deviation
Vital signs (rSIG < 12.7)		
Respiratory rate	16.50	6.41
Heart rate	107.63	30.02
Initial SBP	110.26	37.19
Final SBP	117.17	26.30
Glasgow	7.49	4.68
Analytical parameters (rSIG < 12.7)		
pH	7.26	0.13
BE	–4.65	5.69
Lactate	5.82	4.67
Calcium	1.14	0.10
Hemoglobin	14.79	2.21

rSIG: Reverse Shock Index by Glasgow; SBP: systolic blood pressure; BE: base excess.

Our study has several limitations. First, due to its retrospective design, selection bias cannot be ruled out. Second, patients in CA upon arrival of emergency medical services (EMS) were not included, which may have influenced mortality rate calculations. Third, vital signs and GCS scores used were those recorded upon EMS arrival at the scene and later at the emergency department; however, both measurements were not always available, introducing potential bias. Lastly, the study was limited to one EMS system and four receiving hospitals, which may restrict generalizability, and cutoff values may differ between countries or EMS systems.

Conclusions

From this study, we conclude that rSIG proved to be a reliable, rapid, and easy-to-use index applicable in prehospital settings. It requires no imaging tests or complex formulas, relying solely on clinical variables such as HR, SBP, and GCS. It was the only index to show statistical significance, comparable to internationally validated scales such as RTS.

Therefore, patients with rSIG < 12.7 should be considered potentially severe. However, these results should be interpreted with caution due to the study's design.

Further multicenter studies are needed to validate this index, including subgroup analyses based on trauma type.

ARTICLE INFORMATION

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