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Retrospective Cohort Study

SHOCK INDEX AND ITS VARIANTS AS PREDICTORS OF MORTALITY IN SEVERE TRAUMATIC BRAIN INJURY

SHOCK INDEX AND ITS VARIANTS IN SEVERE TRAUMATIC BRAIN INJURY

Randhall B Carteri, Mateus Padilha, Silvaine Sasso de Quadros, Eder Kroeff Cardoso, Mateus Grellert

Abstract

BACKGROUND

The increase in severe traumatic brain injury (sTBI) incidence is a worldwide phenomenon, resulting in a heavy disease burden in the public health systems, specifically in emerging countries. The shock index (SI) is a physiological parameter that indicates cardiovascular status and has been used as a tool to assess the presence and severity of shock, which is increased in sTBI. Considering the high mortality of sTBI, scrutinizing the predictive potential of SI and its variants is vital.

AIM

This study aims to describe the predictive potential of SI and its variants in sTBI.

METHODS

This study included 71 patients (61 men and 10 women) divided into two groups: Survival (S; $n = 49$) and Non-Survival (NS; $n = 22$). The responses of blood pressure and heart rate were collected at admission and 48 h after admission. The SI, reverse SI (rSI), rSI multiplied by the Glasgow Coma Score (rSIG), and Age multiplied SI (AgeSI) were calculated. Group comparisons included Shapiro-Wilk tests, and independent samples t-tests. For predictive analysis, logistic regression, ROC curves, and AUC measurements were performed.

RESULTS

No significant differences between groups were identified for SI, rSI, or rSIG. The AgeSI was significantly higher in NS patients at 48h following admission (S: 26.32 ± 14.2, and NS: 37.27 ± 17.8; $P = 0.016$). Both the logistic regression and the AUC following ROC curve analysis showed that only AgeSI at 48h was capable of predicting sTBI outcomes.

CONCLUSION

Although an altered balance between heart rate and blood pressure can provide insights into the adequacy of oxygen delivery to tissues and the overall cardiac function, only the Age multiplied SI was a viable outcome-predictive tool in sTBI, warranting future research in different cohorts.

Key Words: Head Trauma; Critical Patient; Neuro-cardio axis; Predictive Tool; Clinical Practice

Core Tip: Patients who suffer severe head trauma are also affected by altered balance between heart rate and blood pressure which influences oxygen delivery to tissues and the overall cardiac function. Although previous studies indicated that SI and its variants could predict the outcomes following TBI the studies were conducted in patients with different severities of injury. Therefore, when evaluating patients who suffered a sTBI, the SI and its variants are not a viable outcome-predictive tool in sTBI, due to similar responses in both surviving and non-surviving patients. However, the Age multiplied SI was a viable outcome-predictive tool in sTBI, warranting future research in different cohorts.

INTRODUCTION

Presently recognized as a significant public health issue, traumatic brain injury (TBI) commonly results in persistent neurological dysfunction [1, 2]. TBI is defined as an alteration in normal brain function resulting from biomechanical forces, caused by rapid acceleration or deceleration of the brain due to motorcycle or automobile accidents; impact resulting from the brain's collision due to falls, motorcycle and automobile accidents, or contact sports; changes in pressure and air displacement due

to explosions; and also, by the penetration of projectiles or objects into the brain [2, 3]. The initial pathophysiological changes resulting from primary mechanical damage can trigger deleterious secondary effects, including progressive neurodegeneration [3]. Additionally, cardiovascular complications are common after TBI, including disturbances in systemic blood pressure, cardiac arrhythmias, and left ventricular dysfunction [4]. Therefore, as these abnormalities are associated with increased morbidity and mortality in TBI, it is plausible that persistent cardiocirculatory dysfunction may underlie some of the pathological features of chronic TBI.

TBI is classified as mild, moderate, or severe, and it can lead to premature death, cognitive alterations, and neuropsychiatric impairments, often compromising the quality of life of surviving individuals [1, 5]. This classification is a combination of various criteria, with the Glasgow Coma Scale being the most commonly used tool [6]. The severity level holds prognostic value but does not necessarily predict the patient's final level of functioning. The pathophysiological mechanisms associated with TBI involve primary injury resulting from mechanical or inertial damage to both white and gray matter, causing membrane rupture, content release, and diffuse axonal injury [7, 8]. Secondary damage refers to the progression of changes associated with the primary brain injury, such as the persistent activation of a series of neurotoxic events, leading to structural damage progression [7]. Thus, the extent and severity of secondary damage are proportional to the trauma intensity and the location of the primary insult, in addition to mechanisms influencing secondary damage, including cardiovascular impairment[9]. Importantly, a complex set of neural pathways, termed the "neuro-cardiac axis," explains cardiac rhythm and hemodynamic disturbances following head trauma [10]. This interaction between the brain and the heart is evident during both primary (due to sympathetic hypertonus, arrhythmias, and cerebral perfusion pressure) and secondary injury (due to catecholamine release, microvascular and myocardial disturbances), as evidenced by conditions such as subarachnoid hemorrhage [4]. In this context, the shock index is a physiological parameter that quantifies the relationship between heart rate and systolic blood pressure [11]. This index serves as an indicator of

cardiovascular status and is widely used as a tool to assess the presence and severity of shock or circulatory disturbances in various medical conditions, including TBI [12, 13].

Hence, to the best of our knowledge, there are no studies that assess the role of SI and its variants as a predictor tool of mortality in sTBI patients without multiple central injuries. The findings of this study can guide future clinical procedures to ensure a positive impact on the prognosis and quality of life of this population. Therefore, this study aims to describe the predictive potential of SI and its variants as an outcome-predictive tool in sTBI patients.

MATERIALS AND METHODS

Study design: This was a prospective observational study by convenience sampling conducted between January 2019 and December of 2022 at the Pronto-Socorro Hospital, a trauma reference center at Porto Alegre, RS, Brazil.

This study followed the ethical precepts, guidelines, and norms established in Resolution No. 466 of 2012 of the National Health Council (CNS), and was carried out only after approval by the Health Research and Ethics Committee of the Municipal Health Secretariat Office of Porto Alegre (CEP SMSPA; registration number: 3.912.623). Patients were identified through registration numbers, which only serves to validate the individuality of the information. The sample was determined in a non-probabilistic way for convenience, selected through the inclusion and exclusion criteria described below, without any discrimination in the selection of individuals or exposure to unnecessary risks. Patients admitted to the adult trauma ICU aged 18 years or older who required enteral or parenteral nutritional therapy were included. The following were excluded from the study: patients with a Glasgow Coma Scale (GCS) score of 9 to 15; patients who were diagnosed with cervical, thoracic or abdominal trauma; patients who received only oral diet, and those with incomplete medical records or records due to lack of data. Of 342 patients admitted to the trauma ICU during the explored period, 71 patients were included in this study.

The study was carried out in the adult trauma ICU of the Hospital de Pronto Socorro de Porto Alegre, with retrospective data, covering the period from January 2019 to December 2022. Data collection was carried out using the institutional Hospital Information System (SIHO), which includes the complete electronic medical record of the patient. The collected variables were: GCS score, injury description, age, sex, days of fasting, body mass, estimated height, blood pressure, and heart rate parameters. Body mass index (BMI = Body Mass / Height^2) was calculated to classify the patients according to the criteria of the World Health Organization [14]. The SI, rSI, and rSIG were calculated as the ratio of HR to SBP (SI = HR/SBP), the ratio of SBP to HR (rSI = SBP/HR), the score of rSI × GCS, and age multiplied by SI (AgeSI = Age x SI) respectively.

Statistical analysis: The general description of the selected data is available through simple and relative frequencies. The normality of distributions of all variables were evaluated using the Shapiro-Wilk test. Student's t test for independent or the Pearson's Chi-Square test was used to compare data between groups. Spearman's rho was used to evaluate the correlation between different variables. To evaluate the predictive potential of SI, rSI, rSIG, and AgeSI we used logistic regression, where regression coefficients (B) were obtained for each variable. When the Wald test values were significant, the odds ratio was calculated to indicate the percentage changes (Exp(B) – 100). Also, Receiver Operator Curves (ROC) analysis was performed. Significant correlations and differences were considered where p < 0.05. All data were analyzed using the Statistical Package for Social Sciences (SPSS) 26.0 statistical program.

RESULTS

Table 1 provides the characteristics of the 72 patients (100% males) included in this study, which were allocated in two distinct groups: survival (S; *n* = 49) and non-survival (NS; *n* = 22). Analysis of the variables indicated that the groups were significantly different regarding mean age (S: 40.51 ± 17.4, and NS: 50.73 ± 14.6; *P* = 0.013), number of days in hospital (S: 28.76 ± 14.6, and NS: 14.36 ± 16.8; *P* = 0.001). No

differences were observed for the other variables, except for the presence of COPD in the non-survival group ($P = 0.032$).

Table 2 presents the data regarding Blood Pressure, Heart Rate, and Different Shock Indexes. The heart rate and the Shock Index at 48h after admission significantly differed between Survival and Non-Survival patients ($P = 0.036$, and $P = 0.03$, respectively). No differences were observed for the other variables, including the different Shock Indexes, except for the AgeSI. The AgeSI was significantly higher in NS patients at 48h following admission (S: 26.32 ± 14.2, and NS: 37.27 ± 17.8; $P = 0.016$). The logistic regression and AUROC results are shown in table 3. When evaluating the significance and the odds ratio to explore further the relationship of different shock indexes with survival odds, no relationship was identified. In patients with sTBI (Figure 1), the AUROC analysis indicated that the predictive accuracy of SI and its variants were insignificant, except for AgeSI at 48h, where the AUROC curve for predicting mortality was 0.727.

DISCUSSION

The present study evaluated the role of SI as a variable to predict the outcomes of sTBI patients coinfected patients. Notably, the different shock indexes were not predictors of outcomes for severe head injury patients, despite the significantly different heart rate and Shock Index responses at 48h following admission between Survival and Non-Survival patients. However, the Age multiplied SI could be a useful tool to predict mortality, showing statistical difference among surviving and non-surviving sTBI patients, and significant predictive value.

The rationale behind the shock index is rooted in the understanding that an altered balance between heart rate and blood pressure can provide insights into the adequacy of oxygen delivery to tissues and the overall cardiac function [15]. Therefore, these physiological responses are directly implicated in survival of TBI patients, due to the relationship with the extent of both primary and secondary damage mechanisms, including restriction of flow in the long pituitary portal vessels after injury [16]. The

predictive value of the shock index in determining mortality in critically ill patients (including TBI patients) has been a subject of investigation in recent studies. Notably, studies such as those conducted by Cannon *et al* [17] and McNab *et al* [18] have contributed to our understanding of the prognostic significance of the shock index in this population. Cannon *et al* [17] conducted a retrospective analysis of TBI patients, elucidating the association between an elevated shock index and increased mortality. Their findings underscored the utility of the shock index as an early prognostic marker, with increased values indicative of higher mortality risk. The study highlighted the clinical relevance of shock index assessment in identifying TBI patients at heightened risk of adverse outcomes [17].

Building upon this foundational work, McNab *et al* [17] conducted a prospective study to further investigate the predictive capabilities of the shock index in severe TBI patients. Their results affirmed a significant association between an elevated shock index on admission and increased mortality, emphasizing the potential utility of this simple yet informative metric in risk stratification and early intervention [18]. In an earlier investigation, Rady *et al* [19] explored the predictive value of the shock index in a broader trauma population, including TBI cases. Their prospective study demonstrated the sensitivity of the shock index in identifying patients at risk of adverse outcomes. Although not specific to TBI, the results provided insights into the potential applicability of the shock index as a valuable tool for early prognostication [19].

Recently, Wu *et al* (2018) contributed to the literature by conducting a retrospective analysis focusing on the shock index and reverse shock index multiplied by Glasgow Coma Scale (GCS) as a predictor of mortality in 2438 patients with isolated head injury. Like the present study, the patients who died were significantly older that those who survived. However, the analysis included patients with different levels of TBI, as indicated by significant differences in the GCS. The study affirmed the independent association between an elevated shock index and mortality, indicating that the rSI is superior to SI as a predictor of mortality in TBI, with comparable predictive power to both the Trauma and Injury Severity Score (TRISS) and Revised Trauma Score

(RTS), further supporting its potential role in risk stratification for TBI patients. Comparatively, in the present study we investigated sTBI patients, which are more prone to have a higher SI score due to the nature of the injury mechanisms. Thus, no differences were identified for SI and its variants among survival and non-survival patients. Interpreting traditional vital signs and the Shock Index (SI) proves challenging when applied to the elderly population. Advanced age is associated with lower heart rate responses and elevated systolic blood pressures, leading to an escalation in false-negative values and influencing SI outcomes with increasing age. To address this issue, previous research suggested that SI multiplied by age (AgeSI) is a better predictor of mortality following traumatic injury of an elderly patient, we also included this variant in the analysis [20, 21]. In the present study, AgeSI showed tendency to significance at admission, and was significantly different at 48h following admission, showing significant predictive value. Our findings those of Kim *et al* [22], showing that the predictive power of the AgeSI for in-hospital mortality was higher in geriatric trauma patients. Therefore, AgeSI is a viable predictive tool in sTBI which is supported by previous research validating AgeSI index [23, 24].

This study is subject to several limitations. Firstly, it relied on a retrospective analysis. Secondly, the exact time profile from injury occurrence to mortality was not measured. While the shock index proves effective in predicting short-term mortality, the lack of a precise timeline from injury to mortality, due to database constraints, limits the comprehensive predictive capacity of the shock index assessment. Rather than presenting an exact time profile, our evaluation focused on the shock index's predictive efficacy for mortality during the emergency department (ED) stay and the overall in-hospital period, respectively. Thirdly, the database did not furnish information regarding the use of anti-hypertensive medications (such as beta blockers), introducing a potential factor that may impact the validity of shock index assessment. Also, the data regarding previous comorbidities rely on the information given by the patients or their caregivers and may present inconsistencies. As for strengths, we highlight the investigation in sTBI patients, the study's originality, and the importance of this study

evaluating the shock index and its variants, an important tool for prognosis in the clinical treatment of critical patients.

CONCLUSION

In conclusion, only Age multiplied by shock index was a viable predictor of mortality following severe head injury. Therefore, future studies should continue to search for cost-effective clinical tools that can predict survival and other outcomes in sTBI patients, considering the cohort-specific characteristics.

ARTICLE HIGHLIGHTS

Research background

Patients who suffer severe head trauma are also affected by altered balance between heart rate and blood pressure which influences oxygen delivery to tissues and the overall cardiac function. Although previous studies indicated that SI and its variants could predict the outcomes following TBI the studies were conducted in patients with different severities of injury.

Research motivation

To the best of our knowledge, there are no studies that assess the role of SI and its variants as a predictor tool of mortality in sTBI patients without multiple central injuries. The findings of this study can guide future clinical procedures to ensure a positive impact on the prognosis and quality of life of this population.

Research objectives

This study aims to describe the predictive potential of SI and its variants as an outcome-predictive tool in sTBI patients.

Research methods

This was a prospective observational study conducted at the Pronto-Socorro Hospital, a trauma reference center at Porto Alegre, RS, Brazil, including 71 patients were included in this study. The study included retrospective data, covering the period from January 2019 to December 2022. The collected variables were: GCS score, injury description, age, sex, days of fasting, body mass, estimated height, blood pressure, and heart rate parameters. Body mass index (BMI = Body Mass / Height2) was calculated to classify the patients according to the criteria of the World Health Organization [14]. The SI, rSI, and rSIG were calculated as the ratio of HR to SBP (SI = HR/SBP), ratio of SBP to HR (rSI = SBP/HR), the score of rSI × GCS, and age multiplied by SI (AgeSI = Age x SI) respectively. Group comparisons included Shapiro-Wilk tests and independent samples t-tests. For predictive analysis, logistic regression, ROC curves, and AUC measurements were performed.

Research results

No significant differences between groups were identified for SI, rSI, or rSIG. The AgeSI was significantly higher in NS patients at 48h following admission (S: 26.32 ± 14.2, and NS: 37.27 ± 17.8; P = 0.016). Both the logistic regression and the AUC following ROC curve analysis showed that only AgeSI at 48h was capable of predicting sTBI outcomes. For AgeSI at 48h, the AUROC curve for predicting mortality was 0.727.

Research conclusions

Patients who suffer severe head trauma are also affected by altered balance between heart rate and blood pressure which influences oxygen delivery to tissues and the overall cardiac function. Although previous studies indicated that SI and its variants could predict the outcomes following TBI the studies were conducted in patients with different severities of injury. Therefore, when evaluating patients who suffered a sTBI, the SI and its variants are not a viable outcome-predictive tool in sTBI, due to similar responses in both surviving and non-surviving patients. However, the Age multiplied

SI was a viable outcome-predictive tool in sTBI, warranting future research in different cohorts.

Research perspectives

Future studies should evaluate the Age multiplied by shock index as an outcome-predictive tool in sTBI.

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