RESEARCH REPORT

CORRELATION BETWEEN SHOCK INDEX AND MORTALITY IN THE PREHOSPITAL AND LEVEL 1 RURAL TRAUMA CENTER EMERGENCY DEPARTMENT SETTINGS

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ABSTRACT

Background: Trauma remains one of the leading causes of death in the United States. The shock index is a valid tool used to detect impending circulatory collapse in the prehospital setting. A ratio of ≥ 0.9 has been shown to have higher rates of mortality than a normal ratio of < 0.7. As validation of the shock index requires high sample sizes, the majority of retrospective studies have been performed at urban level 1 trauma centers. We hypothesized that the shock index would accurately predict mortality in a rural level 1 trauma center.

Objective: Determine if the shock index continues to be a reliable predictive value in trauma patients for morbidity and mortality in rural settings.

Setting: This retrospective study was performed at a state-designated level 1 trauma center in Johnson City, Tennessee. There were 5,090 patients included in the study. The shock index was calculated as heart rate/systolic blood pressure for all patients, both prehospital and on arrival to the emergency department. The patients were divided into three categories: SI ≤ 0.7, 0.71-0.89 and ≥ 0.9. We assessed the relationship between SI, blood product usage and outcome variables using Pearson's correlation coefficients and logistic regression. Chi-square analysis was used to examine the differences between mortality.

Results: Patients with a high SI after arrival to the ED experienced longer hospital stays, ICU and mechanical ventilation days, ISS and blood product usage. Mortality was higher in patients with a SI of ≥ 0.9 in both the prehospital and emergency department settings.

Conclusion: Access to trauma centers continues to be a major issue in the United States, causing overall longer transport times and time to definitive care centers. Based on our study, the SI remains a valid tool for predicting mortality at rural trauma centers, along with predicting need for blood products. With our data, we continue to recommend its usage in both urban and rural trauma centers.

INTRODUCTION

Trauma continues to be one of the leading causes of death in the United States. According to the American Association for the Surgery of Trauma (American Association for the Surgery of Trauma, 2020), it is the fourth leading cause of death for all ages,

and the leading cause of death for individuals aged 1-45. However, it has been shown that many preventable deaths are related to a missed diagnosis of hemorrhagic shock (Eastridge, Holcomb, and Shackelford, 2019). The shock index (SI) was first described as means to improve the detection of impending circulatory collapse in the prehospital setting (Allgöwer & Burri,1967). The patient's vital signs, including heart rate and systolic blood pressure, were obtained by prehospital staff; the ratio of heart rate to systolic blood pressure was calculated and reported to the accepting facility. A ratio of > 0.7 was shown to have higher rates of morbidity than a normal ratio of 0.5-.0.7. The SI was later proven to be a valid marker for significant injury in trauma patients (King, Plewa, Buderer, and Knotts, 1996). Since that time, multiple retrospective studies have been performed that further validate the use of the SI in trauma patients as not only a marker for injury, but as a predictor of both inpatient morbidity and mortality (McNab, Burns, Bhullar, Chesire, and Kerwin, 2013). The use of the SI has been expanded into the treatment of patients with septic shock and pediatric patients. As validation of the SI requires high sample sizes, many retrospective studies have been performed at urban level 1 trauma centers. We sought to justify the use of the SI in a rural level 1 trauma center.

ETHICS STATEMENT

This study was approved with waiver of informed consent by the Institutional Review Board. The authors have reported no financial conflict of interest.

OBJECTIVE

The objective of this study was to determine if the shock index predicts morbidity and mortality in rural trauma patients.

METHODS

This was a retrospective study performed at a state-designated level 1 trauma center in Johnson City, Tennessee. The center primarily serves residents from rural areas, including Northeast Tennessee, Southwest Virginia, Kentucky and western North Carolina. All 5090 patients included in the study were treated by the trauma team between January 1st, 2016, and December 31st, 2019. Patients were excluded from the study if they were under the age of 18, transferred to another facility prior to arrival at our facility, or if insufficient data was available. Each patient's SI was calculated as heart rate/systolic blood pressure. Both the prehospital and emergency department (ED) SI were calculated, with the prehospital vital signs being the first recorded by Emergency Medical Services (EMS). The ED vital signs were the first recorded on arrival. Descriptive data for the patients included total hospital days (LOS), total mechanical ventilation days, total intensive care unit days, disposition, Injury Severity Score (ISS) and transfusion totals. Patients were divided into three categories: SI ≤ 0.7, 0.71-0.89, and ≥ 0.9. These ratios have previously been proven to show statistically significant differences in morbidity and mortality. We assessed the relationship between SI and outcome variables using Pearson Correlation Coefficients and logistic regression. Chi-square analysis was used to examine the differences between mortality and blood product usage based on SI

value. The confidence level was set at 95%. Data were analyzed using Jeffrey's Amazing Statistics Program (JASP, (version 0.14.1.0)), an open-source program supported by the University of Amsterdam, along with Excel (version 2016).

RESULTS

The sex proportions in our population were almost equal (Males 50.5%, Females 45.5%). Males were the majority in groups 0.71- 0.89 and ≥ 0.9 both prehospital and emergency department arrival. In the prehospital setting this was 55.556% with a SI of 0.71- 0.89 and 56.042% with a SI of ≥ 0.9. In the Emergency department 57.157% with a SI of 0.71-0.89 and 56.374% with a SI of ≥ 0.9.

The average age of patients prehospital was 63.9 (IQR 33, Std. 21.317) in the ≤ 0.7 SI group, 50.2 (IQR 36, Std. 21.512) in the 0.71- 0.89 SI group, and 48.2 (IQR 35, Std. 21.174) in the ≥ 0.9 SI group. In the ED, the average age of patients was 62.5 (IQR 34, Std. 21.710) in the ≤ 0.7 SI group, 49.2 (IQR 35, Std. 21.359) in the 0.71- 0.89 SI group, and 48.8 (IQR 35, Std. 21.398) in the ≥ 0.9 SI group.

MORTALITY

In the prehospital setting, patients were 29.5 times more likely to survive with a SI of ≤ 0.7, which was significant. Patients with a SI of ≥ 0.9 had a 75% significant increased risk of death. In the ED, patients were 33 times more likely to survive with a SI of ≤ 0.7, which was significant. Patients with an SI of ≥ 0.9 had a 40% increased risk of death, which was significant (Table 1).

	Odds Ratio (Odds of Survival)	P Values	Confidence Interval
Shock index (prehospital)			
≤ 0.7	29.563	< 0.001	2.937, 3.836
0.71- 0.89	1.302	0.199	0.139, 0.666
≥ 0.9	0.573 (75%)	0.047	-1.105, -0.007
Shock index (emergency department)			
≤ 0.7	33.125	< 0.001	3.160, 3.841
0.71- 0.89	0.913	0.645	-0.475, 0.294
≥ 0.9	0.294 (40%)	< 0.001	-1.723, -0.723

Table 1: Logistic regression of survival for prehospital and emergency department

BLOOD PRODUCTS

In the prehospital setting, patients with a SI of ≥ 0.9 were 2.8 times more likely to require blood products, which was significant. In the ED, patients with a SI of ≥ 0.9 were 3.1 times more likely to require blood products, which was also significant. In both the prehospital and ED settings, patients with a SI of ≤ 0.7 had a significantly lower chance of requiring blood products during their hospitalization.

We determined the direction of the relationships between the variables to SI for patients in the ED with a SI of ≥ 0.9. With this SI level, total hospital days showed a small increase as the SI increased (r(352) = 0.2, P < 0.01),

	Odds Ratio (Odds of Survival)	P Values	Confidence Interval
Shock index (prehospital)			
≤ 0.7	0.07	< 0.001	-2.994, -2.337
0.71- 0.89	0.667	0.004	-0.681, -0.128
≥ 0.9	2.763	< 0.001	0.648, 1.385
Shock index (emergency department)			
≤ 0.7	0.093	<.001	-2.652, -2.109
0.71- 0.89	0.935	0.619	-0.329, 0.196
≥ 0.9	3.138	< 0.001	0.761, 1.526

Table 2: Logistic regression of blood product usage in the prehospital and emergency department.
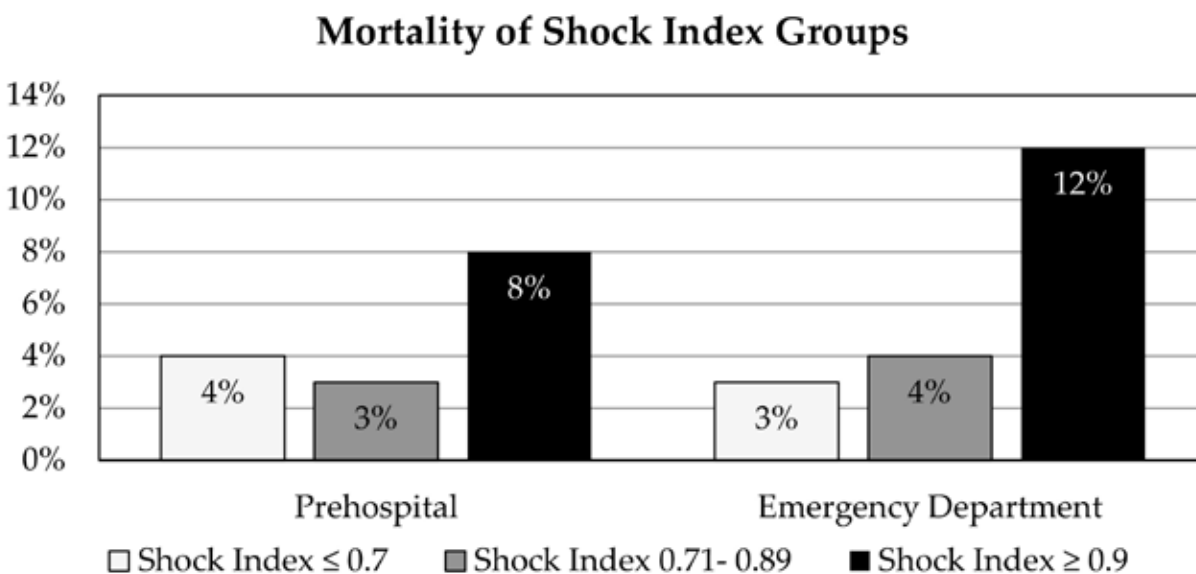
Mortality of Shock Index Groups

Figure 1: Mortality rates between shock index levels prehospital and emergency department.

total ICU days showed a small increase as the SI increased (r(352) = 0.27, P < 0.01), total ventilator days showed a small increase as the SI increased (r(352) = 0.22, P = 0.02), ISS showed a small increase as the SI increased (r(352) = 0.26, P < 0.01), packed red blood cells showed a small increase as the SI increased (r(352) = 0.31, P < 0.01), plasma (r(352) = 0.19, P < 0.01), platelets showed a small increase as the SI increased (r(352) = 0.2, P < 0.01), other blood substitute showed a small increase as the SI increased (r(352) = 0.21, P < 0.01) and total blood products showed a small increase as the SI increased (r(352) = 0.32, P < 0.01).

DISCUSSION

Trauma remains one of the leading causes of death in the United States. In Tennessee, the current trauma destination guidelines include Glascow Coma Score, systolic blood pressure, respiratory rate and anatomy of the injury. The SI is a quantifiable value proven to predict higher levels of mortality in trauma patients. Data from research on the SI have been primarily obtained from urban trauma centers. The goal of our study was to further validate its use in rural trauma centers, where the data has been scarce.

Access to trauma centers continues to be a major issue across the United Sates. In the 2010 United States Census, approximately 29.7 million Americans lived more than one hour away from a level 1 or 2 trauma center. With longer transport times, patients' vital signs are more likely to change. The need for a reliable index for rural trauma patients becomes grossly apparent.

Our study included 5,090 patients, all above the age of 18. As hypothesized, a lower SI (≤ 0.7) in both prehospital and ED patients had a higher rate of survival and a lower rate of need for transfusion. Patients with a SI ≥ 0.9 in both prehospital and ED patients had increased chances for mortality and need for transfusion. These findings correlated

well with previous studies published about the SI in urban centers. The need for blood products in patients with elevated shock index is a significant finding as many rural non-trauma centers have limited access to blood products. A similar study using data from the Trauma Quality Improvement Program Database (TQIP) validated the correlation between a SI of > 1 and higher mortality, need for transfusion and resource utilization (Jehan et al, 2019). The study included 144,951 patients over two years from the TQIP. While our study included a smaller sample size, our data was noted to be similar to the data found at a sample of urban trauma centers.

As mentioned in the results section, we also noted positive correlations between a SI of ≥ 0.9 and multiple other outcome variables, including total ICU/hospital days, total ventilator days and specific blood products. The strongest positive correlation was between a SI of ≥ 0.9 and total amount of blood products (r=0.32). Again, the data from our rural center correlated well with data obtained from a level 1 trauma center in Jacksonville, Florida. This study found a significant positive correlation between a higher SI and average number of blood products, along with total hospital, ICU and ventilator days (King et al, 1996). The importance of SI and transfusion should be explored by EMS. A previous study evaluated the use of SI and pulse pressure as a reliable system for predicting patients in the prehospital setting that will require blood products (Plodr et al, 2023). A second study revealed patients with a SI > 1.0 had a higher probability of receiving a blood transfusion (Ortiz-Morales, 2020). These studies, coupled with our data, further validate the need to monitor SI in the prehospital setting to determine patients who are likely to require blood products.

Since the finalization and analysis of our data, we have implemented the use of the SI in our own trauma activation criteria. To facilitate ease of use, our criteria states that a heart rate greater than systolic blood pressure automatically meets highest priority (SI of >1.0). The American College of Surgeons also has recently implemented the SI in their "National Guidelines for the Field Triage of Injured Patients". Patients whose heat rate is greater than systolic blood pressure meet "red criteria", designating them at the highest risk for serious injury (American College of Surgeons, 2021).

LIMITATIONS

Some limitations of our study were data collection in the prehospital setting. We did not evaluate or take into account prehospital interventions done buy EMS such as the differences in manual versus mechanical blood pressures, administration of prehospital IV fluid, comorbidity factors, types of injuries, or an in-depth analysis of age. These may contribute to the decrease in SI values enroute to the ED. We also did not observe comparisons between patients that received advanced versus basic life support. A future direction may involve evaluation of such data to bring further insight to the SI as a predictive value.

Despite efforts to establish accurate documentation in our system, the possibility of error when documenting heart rate and blood pressure will always exist. It is possible data points were inaccurately or never recorded. Finally, this is a single institutional study and does not represent the entire rural population.

CONCLUSIONS

The shock index continues to be a reliable predictive value in trauma patients for morbidity and mortality. A SI of ≥ 0.9 in both the prehospital and emergency department settings had greater need for transfusion and higher mortality rates. There continues to be a need for further education of emergency medical services regarding the utility of the SI, as this is not a part of standard EMS training. With our data and results coming from a rural area and showing similar findings to urban areas, we continue to recommend its usage in both urban and rural trauma centers.

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