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ORIGINAL RESEARCH

Modifying effects of alcohol use and age on the predictive performance of prehospital shock index for functional and survival outcomes in severe trauma patients

Young Ju Cho[1], Yong Soo Cho[2], Eujene Jung[2], Byeong Jo Chun[3,*], Ho Goon Kim[4,*], Hyun Yi Kook[5,*]

[1]Department of Psychiatric medicine, Haenam Woori General Hospital, 59021 Haenam, Republic of Korea
[2]Department of Emergency Medicine, Chonnam National University Hospital, 61469 Gwangju, Republic of Korea
[3]Department of Emergency Medicine, Chonnam National University, 61469 Gwangju, Republic of Korea
[4]Department of Surgery, Chonnam National University Medical School, 61469 Gwangju, Republic of Korea
[5]College of Nursing, Chonnam National University, 61469 Gwangju, Republic of Korea

***Correspondence**
em00016@cnuh.ac.kr
(Byeong Jo Chun);
ge00040@cnuh.ac.kr
(Ho Goon Kim);
em00063@cnuh.ac.kr
(Hyun Yi Kook)

Abstract

This study investigated whether the prehospital shock index (SI) could predict clinical outcomes in trauma patients, with or without pre-injury alcohol consumption, and whether this predictive capacity varied by age. We conducted a retrospective study on severe trauma patients transported to a level-1 trauma center by emergency medical services from 2015 to 2021. Our primary exposure was abnormal SI, defined as an SI $\geq$0.9, with in-hospital mortality and poor functional outcomes as study outcomes of interest. Multivariable logistic regression analysis estimated the effect of SI on clinical outcomes. Our findings indicated a significant association between abnormal SI and poor functional outcomes in all trauma patients (adjusted odds ratio: 2.15; 95% confidence interval: 1.41–3.28), notably pronounced in the older age group (adjusted odds ratio: 3.56; 95% confidence interval: 1.55–8.30). However, no association was found with in-hospital mortality. Importantly, among severe trauma patients who did not consume alcohol, abnormal SI was significantly associated with poor functional outcomes, irrespective of age, and with increased in-hospital mortality exclusively in the older age group. Thus, abnormal SI significantly predicted clinical outcomes in non-alcohol-consuming severe trauma patients, with the predictive power for in-hospital mortality being specifically significant in older, non-alcohol-consuming patients.

Keywords

Shock index; Trauma; Alcohol

1. Introduction

The identification of patients at a high risk of mortality is a crucial aspect in managing trauma patients. Among several models for predicting the survival outcome of such patients, the Trauma Score and Injury Severity Score is the most widely used algorithm [1, 2]. While the Trauma Score and Injury Severity Score accurately predicts trauma patient mortality, its utility in prehospital stages or emergency departments (EDs) is limited due to the complexity of its calculation and the requirement for comprehensive knowledge of patient injuries across all affected organs [3, 4]. The Shock Index (SI), defined as heart rate (HR) divided by systolic blood pressure (SBP), has been identified as a more sensitive shock marker than conventional vital signs alone. It is also a significant injury marker when SBP and HR are normal, as SBP is a late shock indicator following trauma [5–7]. Previous studies have demonstrated an association between both prehospital and hospital SI and factors such as hospital length of stay, transfusion requirement and patient mortality [8–11]. Acute alcohol consumption is associated with a significant number of both fatal and non-fatal injuries [12, 13], accounting for approximately 10% of the total impact of alcohol on health (9.9% in low-income countries and 12.6% in high-income countries) [14]. However, the association between alcohol consumption and trauma patient clinical outcomes remains contested [15, 16]. While moderate to heavy alcohol consumption increases SBP and promotes HR variability, influencing SI irrespective of trauma severity [17, 18], to our knowledge, no study has directly explored the SI variation pattern among trauma patients based on prehospital alcohol use. Age is an important factor influencing outcomes after injury. Increased age, alongside diminished physiologic reserve, metabolic and hormonal responses are acknowledged risk factors for poorer clinical outcomes post-trauma [19, 20]. Previous studies have indicated that the changes in SBP and HR due to alcohol consumption vary by age [21, 22]. Additionally, the SI accuracy across all age groups is a subject of debate due to variations in physiologic variables, including SBP and HR in older patients [23]. Further studies are warranted to clarify the predictive performance of prehospital SI in severe trauma patients, particularly with regard to the interaction effects of prehospital alcohol use and age on its predictive performance. This study aimed to examine whether the SI, measured at the prehospital stage by emergency medical services (EMS), could predict clinical outcomes among trauma patients and whether the predictive capability of prehospital SI is influenced by prehospital alcohol consumption and age.

2. Materials and methods

2.1 Study design, setting and data sources

We conducted a retrospective study of trauma patients transported to the Chonnam National University Hospital (CNUH), a level-1 trauma center by EMS. In Korea, EMS use a "scoop and run" system, initiating transport after vital signs, such as blood pressure, HR, respiration rate and body temperature have been measured, and after a physical injury examination has been conducted. EMS provide essential treatments like simple wound dressing and the placement of neck braces and splints at the scene. Fluid resuscitation is initiated under direct medical control when hypotension or massive bleeding is suspected or observed. If severe trauma is suspected or observed, patients are transferred to the nearest level-1 trauma center or ED.

Since its establishment in 2010, the CNUH trauma center, which serves Gwangju (population: approximately 1.42 million) and Chonnam provinces (population: 3.35 million inhabitants per 12,678 km^2), operates a team of specialists from various departments, including neurosurgery, general surgery, thoracic surgery, orthopedic surgery, radiology and emergency medicine. If EMS paramedics suspect a patient to have major trauma, including traumatic brain injury, the hospital is informed from the trauma scene or during transport. Upon arrival at the hospital, physical examinations, including neurologic examination, laboratory tests and brain/abdomen/chest computed tomography, are immediately conducted. Emergency surgery is performed around the clock if radiologic examination identifies an injury requiring surgical treatment. Post-surgery, based on their condition, patients are admitted to a specialized trauma ward or trauma intensive care unit.

Prehospital EMS data were gathered from ambulance run sheets and EMS dispatch records. Information on hospital treatment and clinical outcomes was extracted from inpatient discharge records in the ED, intensive care units and general wards. Long-term outcome information was collected *via* telephone surveys 1 and 6 months after hospital discharge. The collected data were cleaned and managed by the Data Quality Control board to address invalid and/or incomplete entries.

2.2 Study population

Our study population comprised severe trauma patients, with an Injury Severity Score $\geq$16, aged $\geq$18 years, who were transported to the CNUH trauma center by EMS between January 2015 and December 2021. Patients lacking vital sign information measured at the scene, information on prehospital alcohol use, or information about clinical outcomes at hospital discharge were excluded.

2.3 Main outcome

Our primary outcome measure was in-hospital mortality. The secondary outcome was the functional outcome at hospital discharge, measured according to the modified Rankin scale (m-RS) [24]. The m-RS is scored from 0 to 6, with 0 indicating no disability and 6 signifying death. Poor functional recovery was defined as an m-RS score of 4, 5 or 6.

2.4 Variables and measurement

The primary exposure of our study was abnormal SI, defined as SI $\geq$0.9 [25]. We gathered data on patient demographics (age, sex), injury characteristics (place of injury, activity at the time of injury, mechanism of injury and alcohol consumption prior to injury), prehospital care (oxygen and fluid resuscitation), vital signs at the ED including SBP and HR, severity of trauma measured by the New Injury Severity Scale, and clinical outcomes at the time of hospital discharge.

2.5 Statistical analysis

We compared patient characteristics according to the prehospital SI measured at the scene (normal or abnormal) using the chi-square test for categorical variables and the Wilcoxon rank-sum test for continuous variables.

Multivariable logistic regression analyses were performed to estimate the effect size of prehospital SI for mortality and poor functional outcome at hospital discharge after adjusting for potential confounders. Adjusted odds ratios (AORs) with 95% confidence intervals (CIs) were calculated. We also conducted interaction analyses to explore whether prehospital alcohol use (alcohol use *vs.* no alcohol use) and age (18–64 years *vs.* 65–120 years) modify the predictive performance of prehospital SI by including interaction terms in the regression models. We further performed stratified analyses according to alcohol use (alcohol use *vs.* no alcohol use) and age (18–64 years *vs.* 65–120 years).

All statistical analyses were carried out using SAS version 9.4 (SAS institute Inc., Cary, NC, USA). All p-values were two-tailed, with $p < 0.05$ considered statistically significant.

3. Results

3.1 Demographic findings

A total of 719 severe trauma patients were included in the final analysis, excluding patients with mild trauma (Abbreviated Injury Scale score $<$16), those aged under 18 years, and those with missing data on HR, SBP or clinical outcomes. Table 1 shows the characteristics of the study sample, categorized by prehospital SI.

Of all severe trauma patients, 17.0% (122/719) had consumed alcohol before the injury and 83.0% (597/719) had not.

Among the 719 total patients, 17.0% (122/719) had an abnormal SI ($>$0.9), while the remaining 83.0% (597/719) had a normal SI. The rate of poor functional outcomes was significantly higher in patients with abnormal SI (51.6%, 63/122) relative to those with normal SI (34.0%, 203/597) ($p < 0.01$). However, there was no significant difference in mortality before hospital discharge based on SI (p = 0.31).

TABLE 1. Characteristics of severe trauma patients according to shock index.

Variables	Total	Prehospital Shock Index		*p*-value
		Abnormal (≥0.9)	Normal (<0.9)	
Total	719 (100.0)	122 (17.0)	597 (83.0)	
Age, yr				
18–64	480 (66.8)	89 (73.0)	391 (65.5)	0.11
65–120	239 (33.2)	33 (27.0)	206 (34.5)	
Sex, male	466 (64.8)	81 (66.4)	385 (64.5)	0.69
Alcohol use, yes	168 (23.4)	26 (21.3)	142 (23.8)	0.14
Place of injury, home	258 (35.9)	33 (27.0)	225 (37.7)	0.03
Activity before injury				
Work	102 (14.2)	12 (9.8)	90 (15.1)	<0.001
Leisure	145 (20.2)	37 (30.3)	108 (18.1)	
Other	472 (65.6)	73 (59.8)	399 (66.8)	
Mechanism of injury				
Traffic accident	224 (31.2)	50 (41.0)	174 (29.1)	0.03
Fall	208 (28.9)	32 (26.2)	176 (29.5)	
Other	287 (39.9)	40 (32.8)	247 (41.4)	
Injury area				
Head	275 (38.2)	44 (36.1)	231 (38.7)	0.59
Neck and face	156 (21.7)	17 (13.9)	139 (23.3)	0.02
Chest	207 (28.8)	53 (43.4)	154 (25.8)	<0.001
Abdomen	123 (17.1)	40 (32.8)	83 (13.9)	<0.001
Spine	53 (7.4)	8 (6.6)	45 (7.5)	0.71
Extremity	242 (33.7)	55 (45.1)	187 (31.3)	<0.001
Other	236 (32.8)	41 (33.6)	195 (32.7)	0.84
Prehospital GCS				
Alert	445 (61.9)	64 (52.5)	381 (63.8)	0.11
Drowsy	76 (10.6)	15 (12.3)	61 (10.2)	
Stupor	47 (6.5)	9 (7.4)	38 (6.4)	
Coma	151 (21.0)	34 (27.9)	117 (19.6)	
Prehospital advanced airway, yes	114 (15.9)	31 (25.4)	83 (13.9)	<0.001
Prehospital fluid resuscitation, yes	29 (4.0)	5 (4.1)	24 (4.0)	0.97
ER SBP (mmHg), mean (IQR)	130 (110–150)	100 (80–110)	133 (120–152)	<0.001
ER HR (times/min), mean (IQR)	84 (75–98)	106 (92–120)	80 (73–92)	<0.001
ISS, mean (IQR)	22 (17–29)	22 (19–29)	22 (17–29)	0.12
Clinical outcomes				
Poor functional outcome	266 (37.0)	63 (51.6)	203 (34.0)	0.008
In-hospital mortality	92 (12.8)	19 (15.6)	73 (12.2)	0.31

Abbreviations: Yr, year; GCS, Glasgow Coma Scale; ER, emergency room; SBP, systolic blood pressure; IQR, interquartile range; HR, heart rate; ISS, injury severity score.

Characteristics of the study population according to alcohol use and age group are shown in **Supplementary Tables 1 and 2**. Table 2 presents the relationship between SI and study outcomes, stratified by alcohol use and age group.

3.2 Main analysis

In the multivariable logistic regression analysis, a significant association between abnormal SI and poor functional outcome was observed (AOR: 2.15; 95% CI: 1.41–3.28). However, no significant association was found between abnormal SI and in-hospital mortality (AOR: 1.32; 95% CI: 0.75–2.32) (Table 3).

Stratified analysis according to age group revealed that abnormal SI significantly increased the risk of poor functional outcomes in both younger (18–64 years; AOR: 1.78; 95% CI: 1.08–2.93) and older (65–120 years; AOR: 3.59; 95% CI: 1.55–8.30) age groups, with a statistically significant difference in effect sizes (p for interaction < 0.05). Similar results were observed for in-hospital mortality, with age significantly modifying the association between prehospital SI and the outcome (p for interaction < 0.05). Abnormal SI was significantly associated with increased in-hospital mortality only in the older age group (AOR: 3.45; 95% CI: 1.50–7.90).

In trauma patients with prehospital alcohol use, no significant association was found between abnormal SI and increased poor functional outcome (AOR: 0.78; 95% CI: 0.29–2.06) or in-hospital mortality (AOR: 0.58; 95% CI: 0.18–1.88). Similarly, for trauma patients without prehospital alcohol use, abnormal SI was not associated with increased poor functional outcome (AOR: 0.68; 95% CI: 0.24–1.94) or in-hospital mortality (AOR: 0.41; 95% CI: 0.12–1.48).

The trends observed in the alcohol use and age interaction analyses were consistent when considering the predictive performance of prehospital SI on clinical outcomes, with interactions of both alcohol use and age accounted for. Abnormal SI was significantly associated with poor functional outcomes among severe trauma patients without prehospital alcohol use, irrespective of age group. However, it was only significantly associated with in-hospital mortality in the older age group (Table 3).

TABLE 2. Outcomes of subgroups by prehospital alcohol use and age group.

Variables	Trauma patients with traumatic brain injury			
	All	Shock index		p-value
		Abnormal (>0.9)	Normal (≤0.9)	
Total	719 (100.0)	122 (100.0)	597 (100.0)	
Poor functional outcome	266	63	203	<0.001
Prehospital alcohol use				
Yes	50 (18.8)	7 (11.1)	43 (21.2)	<0.001
No	216 (81.2)	56 (88.9)	160 (78.8)	
Age group, yr				
18–64	157 (59.0)	40 (63.5)	117 (57.6)	<0.001
65–120	109 (41.0)	23 (36.5)	86 (42.4)	
Prehospital alcohol use & age, yr				
Alcohol use & 18–64	35 (13.2)	4 (6.3)	31 (15.3)	<0.001
Alcohol use & 65–120	15 (5.6)	3 (4.8)	12 (5.9)	
No alcohol use & 18–64	122 (45.9)	36 (57.1)	86 (42.4)	
No alcohol use & 65–120	94 (35.3)	20 (31.7)	74 (36.5)	
In-hospital mortality	92	19	73	<0.001
Prehospital alcohol use				
Yes	35 (38.0)	4 (21.1)	31 (42.5)	<0.001
No	57 (62.0)	15 (78.9)	42 (57.5)	
Age group, yr				
18–64	50 (54.3)	7 (36.8)	43 (58.9)	<0.001
65–120	42 (45.7)	12 (63.2)	30 (41.1)	
Prehospital alcohol use & age, yr				
Alcohol use & 18–64	21 (22.8)	1 (5.3)	20 (27.4)	<0.001
Alcohol use & 65–120	14 (15.2)	3 (15.8)	11 (15.1)	
No alcohol use & 18–64	29 (31.5)	6 (31.9)	23 (31.5)	
No alcohol use & 65–120	28 (30.4)	9 (47.4)	19 (26.0)	

TABLE 3. Multivariable logistic regression analysis examining the association between prehospital shock index and outcomes with and without interactions of alcohol use and age.

Poor functional outcome	Shock index		p for interaction
	Normal	Abnormal	
Total	ref.	2.15 (1.41–3.28)	
Age, yr			
18–64	ref.	1.78 (1.08–2.93)	<0.001
65–120	ref.	3.59 (1.55–8.30)	
Alcohol use			
Yes	ref.	0.78 (0.29–2.06)	0.44
No	ref.	0.68 (0.24–1.94)	
Alcohol use & age, yr			
Alcohol use & 18–64	ref.	0.55 (0.16–1.96)	<0.001
Alcohol use & 65–120	ref.	1.14 (0.16–8.25)	
No alcohol use & 18–64	ref.	2.24 (1.27–3.97)	
No alcohol use & 65–120	ref.	4.61 (1.76–12.10)	
In-hospital mortality			
Total	ref.	1.32 (0.75–2.32)	
Age			
18–64	ref.	0.63 (0.27–1.46)	<0.001
65–120	ref.	3.45 (1.50–7.90)	
Alcohol use			
Yes	ref.	0.58 (0.18–1.88)	0.17
No	ref.	0.41 (0.12–1.48)	
Alcohol use & age, yr			
Alcohol use & 18–64	ref.	0.19 (0.02–1.55)	<0.001
Alcohol use & 65–120	ref.	1.00 (0.15–6.83)	
No alcohol use & 18–64	ref.	0.90 (0.34–2.36)	
No alcohol use & 65–120	ref.	4.76 (1.79–12.66)	

Adjusted with age, sex, place of injury, activity before injury and injury mechanism.

4. Discussion

Our retrospective observational study aimed to evaluate the predictive utility of SI on clinical outcomes among severe trauma patients, focusing on variations in prehospital alcohol use and age group. We found that the SI did not forecast functional and survival outcomes in trauma patients who had consumed alcohol before injury. Moreover, we observed that the SI's predictive power was considerably stronger in patients over 65 years old who had not consumed alcohol relative to the younger age group.

SI, a measure calculated using vital signs, such as SBP and HR, provides a useful tool for patient triage and prehospital treatment decisions, such as fluid resuscitation. It is also invaluable for identifying critically ill trauma patients, even if their SBP and HR are within normal ranges. Previous research has demonstrated that an SI $\geq$1 is a significant predictor of mortality and other clinical outcomes, guiding appropriate treatments, including fluid therapy and massive transfusion [7, 26]. Studies have shown patients with an SI $\geq$1 exhibit over four times the in-hospital mortality than patients with an SI <1 [27].

In contrast, our study, which focused on severe trauma patients, found that an SI $\geq$0.9 predicted poor functional outcomes but did not significantly predict in-hospital mortality. This may be attributed to the specific patient population we focused on, as previous studies with better predictive performance of SI on in-hospital mortality considered trauma patients of varying severity.

To our knowledge, this was the first study to analyze how alcohol consumption affects the predictive performance of SI among severe trauma patients. We found that, while the SI remained a useful predictor for poor functional outcomes among patients who did not consume alcohol, an abnormal SI did not predict poor outcomes or in-hospital mortality among patients who drank alcohol prior to their trauma. Previous studies have suggested alcohol consumption can increase HR and induce variability in SBP [28, 29], which may explain our findings.

Aging is a significant risk factor for poor functional and survival outcomes among trauma patients [30]. We found older patients (≥65 years of age) had significantly worse functional outcomes and higher in-hospital mortality rates. Moreover, the predictive power of SI for these outcomes was considerably higher in this age group, especially in those who had not consumed alcohol. This may be due to a higher incidence of pre-existing hypertension among older patients and their rigid BP responses to external factors like bleeding [31, 32].

Our study suggests that the prehospital SI may not be a reliable predictor of clinical outcomes in severe trauma patients who consume alcohol before their trauma or in younger patients. Consequently, it might be unproductive to use a standard SI as a predictive indicator for these patient groups. These results could provide a foundation for proposing new SI cut-off values, taking into account alcohol use and age.

Our study had several limitations. The identification of prehospital alcohol use was subjective and not based on blood alcohol concentration (BAC) measurements, which could introduce bias. Furthermore, although changes in patients' SBP and HR can vary with BAC levels [33], our study did not consider BAC. We also set the SI cut-off at 0.9, potentially including patients with less severe conditions and reducing the specificity of our findings. Additionally, our study only considered severe trauma patients with an Injury Severity Score of ≥16, which might not fully reflect the severity or diversity of injuries. Finally, as a single-center study with a small sample size, our findings may have limited internal and external validity and thus should be interpreted cautiously. Future multicenter studies with larger populations are recommended. It is also important to note that our study design was observational, not a randomized controlled trial, and as such, potential biases from unmeasured confounders that were not controlled for may exist.

5. Conclusions

Abnormal prehospital SI is notably associated with worse functional outcomes in severe trauma patients, but this association is influenced by factors such as prehospital alcohol use and age. SI does not predict functional and survival outcomes in severe trauma patients who consumed alcohol before the incident the led to hospitalization. Furthermore, among patients who did not use alcohol pre-incident, SI demonstrates better predictive performance in older age groups relative to younger ones. Consequently, even if the prehospital SI is normal, poor clinical outcomes should not be dismissed in severe trauma patients who have used alcohol prior to the incident. Additional research is necessary to determine the appropriate cut-off value for SI that predicts clinical outcomes based on prehospital alcohol use and age.

AVAILABILITY OF DATA AND MATERIALS

The data of this study were obtained from the Korea Centers for Disease Control and Prevention, but restrictions apply to the availability of these data, which are not publicly available.

AUTHOR CONTRIBUTIONS

YJC and EJ—conceptualization; YSC and HGK—data curation; BJC, HGK and HYK—formal analysis, supervision; YJC and HYK—investigation, software, writing original draft, writing review and editing; EJ—methodology. All authors have read and agreed to the published version of the manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The study protocol was reviewed and approved by the Institutional Review Board of Chonnam National University Hospital (CNUH-2018-297). The requirement for informed consent from patients was waived because the study was a retrospective analysis of existing data.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

SUPPLEMENTARY MATERIAL

Supplementary material associated with this article can be found, in the online version, at `https://oss.jomh.org/files/article/1707277748485931008/attachment/Supplementary%20material.docx`.

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