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ORIGINAL RESEARCH

Associated Factors of Trauma Severity and Mortality in Pediatric Patients Admitted to Intensive Care Unit; a 10-Year Retrospective Study

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Abstract: **Introduction:** Trauma is a significant global public health concern and the leading cause of morbidity and mortality in children. This study aimed to assess the independent predictors of trauma severity as well as mortality in pediatric patients admitted to the intensive care unit (ICU). **Methods:** In this cross-sectional study, following the STROBE checklist, we retrospectively analyzed the clinical and baseline characteristics of pediatric patients with trauma injuries admitted to the ICU of Children's Hospital of Zhejiang University School of Medicine, China, over a decade. **Results:** 951 pediatric patients with a mean age of 4.79 ± 3.24 years (60.78% Boys) were studied (mortality rate 8.41%). Significant associations were observed between ISS and place of residence (p = 0.021), location of the injury (p = 0.010), year of injury (p <0.001), and injury mechanism (p <0.001). The two independent factors of trauma severity were the year of injury (= 0.47; 95%CI: 0.28 – 0.65) and injury mechanism (= -0.60; 95%CI: -0.88 - -0.31). Significant differences were observed between survived and non-survived regarding age (p <0.001), ISS score (p <0.001), time elapsed from injury to ICU (p <0.001), duration of mechanical ventilation (p <0.001), GCS score (p <0.001), and the proportion of patients requiring mechanical ventilation (p <0.001). The results of multivariate analysis indicated that age (OR = 0.805; 95%CI: 0.70 - 0.914; p = 0.001) and GCS score at ICU admission (OR = 0.629; 95%CI: 0.53 - 0.735; p < 0.001) acted as protective factors, whereas mechanical ventilation in the ICU (OR = 7.834; 95%CI: 1.766 - 34.757; p = 0.007) and ISS score at ICU admission (OR = 1.088; 95%CI: 1.047 - 1.130; p < 0.001) served as risk factors for mortality. **Conclusions:** Automobile-related injuries represent the leading cause of trauma in children, with escalating severity scores year over year among pediatric patients admitted to the ICU with trauma injuries. Based on the findings the independent predictors of mortality of pediatric trauma patients admitted to the ICU were age, GCS score at ICU admission; mechanical ventilation in the ICU, and ISS score at ICU admission. Also, the year of injury and injury mechanism were independent predictors of trauma severity.

Keywords: Pediatrics; Trauma; Critical Care; Prognosis

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1. Introduction

Trauma, defined as the mechanical disruption of human tissues or organs (1), constitutes a significant global public health concern and is the leading cause of morbidity and mortality in children (2, 3). Data from China's National Disease Surveillance System underscores the rising trend of unintentional injuries as the chief cause of death among children aged 1–14 years, with an alarming annual increase in incidence ranging between 7% and 10% (4). Traumatic injuries represent the most prevalent form of such incidents, outnumbering the combined total of all other injury types (5).

The international academic community identifies pediatric trauma as a seminal 21st-century health issue and a forefront topic in pediatric healthcare (6). It significantly contributes to childhood disability and represents the leading cause of fatality in children. The physiological immaturity of children's bodies exacerbates the complexity of trauma management, resulting in elevated rates of disability and mortality in this patient group (6).

Trauma has emerged as a crucial determinant undermining the physical health and safety of children and imposes substantial physical and psychological burdens on the children and their families (7). The incidence of pediatric trauma has exhibited a persistent upward trend in recent years (8). A thorough analysis of the prognostic factors and management of pediatric trauma in intensive care units is crucial for effective treatment. Literature has reported on the impact of various trauma scores, such as the Glasgow Coma Scale (GCS) and Injury Severity Score (ISS), on the prognosis of pediatric trauma patients; however, these studies typically indicate only a trend without providing conclusive evidence (9,

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10). Based on the above-mentioned, this study aimed to assess the independent predictors of trauma severity as well as mortality in pediatric trauma patients admitted to the intensive care unit (ICU).

2. Methods

2.1. Study design and setting

In this cross-sectional study, following the STROBE checklist, we retrospectively analyzed the clinical and baseline characteristics records of pediatric patients with trauma injuries admitted to the ICU of Children's Hospital of Zhejiang University School of Medicine, China, over a decade (between January 1, 2009, and December 31, 2018).

Children's Hospital of Zhejiang University School of Medicine is the earliest and largest tertiary hospital and the most comprehensive center for pediatric healthcare in Zhejiang Province. The hospital is among China's first children's hospitals, with a National Clinical Research Center for Child Health and a National Children's Regional Medical Center. Its comprehensive strength ranks in the top tier of children's hospitals nationwide. The hospital has a dedicated emergency trauma surgery department and a surgical intensive care unit. Indipendent-associated factors of mortality and trauma severity based on injury severity score (ISS) were evaluated.

This study adhered to the principles of the Declaration of Helsinki and was approved by the ethics committee of the children's hospital affiliated with Zhejiang University School of Medicine (Hangzhou, China; approval number: 2024-IRB-0127-P-01). Given this report's retrospective nature and minimal risk, written informed consent was waived.

2.2. Participants

The inclusion criteria for this study comprised (1) patients who were admitted to the intensive care unit (ICU) between January 1, 2009, and December 31, 2018; (2) patients aged <18 years; and (3) patients whose initial incidents responsible for trauma were falls, automobile accidents, machinery-related incidents, or other accidental injuries. The exclusion criteria were (1) patients with intracranial injuries spontaneously arising from neurological disorders, including conditions such as spontaneous intracranial hemorrhages, brain tumors, and epilepsy; (2) patients with a preinjury cardiac function Class II or higher (classified as New York Heart Association); (3) patients with hepatic dysfunction categorized as Child-Pugh Class B or above; and (4) pediatric patients diagnosed with congenital metabolic disorders.

2.3. Data gathering

Data collection included the child's gender, age, place of residence, residential status, time of injury, location of injury, cause of injury, site of injury, post-injury management, and outcome. Specifically, details regarding post-injury care were recorded, including: 1. Time from injury to ICU admission, 2. Whether emergency surgical intervention was required, 3. Whether mechanical ventilation was needed during the ICU stay and if so, the duration of mechanical ventilation, 4. Length of stay in the ICU and total hospitalization days, and 5. GCS scores at both ICU admission and discharge and the ISS score at ICU admission.

2.4. Definitions

The Abbreviated Injury Scale (AIS) is recognized worldwide as the standard method for assessing injury severity(11) . The ISS, derived from the squared sum of the highest AIS scores from three different body regions, effectively predicts mortality in patients with multiple trauma injuries (12-14). Research has shown that the ISS scoring system outperforms the Revised Trauma Score scoring system in terms of forecasting mortality, survival probabilities, and length of ICU stay, thereby offering high predictive accuracy for patient outcomes (15). Reports indicate that trauma with an ISS of 20 points is strongly correlated with fatal outcomes and that patients with an ISS of >50 rarely survive (16).

Studies have also indicated that when the total ISS exceeds 40, the mortality rate escalates, with severely to critically injured patients accounting for 53.6

2.5. Statistical analysis

A retrospective analytical approach was used to gather and compile data pertaining to pediatric patients with trauma. Data organization and analysis were conducted using Statistical Package for the Social Science software (SPSS) version 26.0 (IBM, Armonk, New York, USA). A statistical significance level was set at $P<0.05$. Categorical variables related to the basic demographic information of pediatric trauma patients were described as frequencies and percentages. Continuous variables, such as the Injury Severity Score (ISS), are expressed using mean ± standard deviation (x±s). Independent samples t-tests and one-way analysis of variance were used to compare differences in ISS scores across various demographic categories, assessing for any disparities in injury severity based on these factors. A multiple stepwise regression analysis was conducted to evaluate the independent predictors of mortality and trauma severity based on ISS.

3. Results

3.1. General Characteristics

We enrolled 951 pediatric patients younger than 18 years who were admitted to the ICU between January 1, 2009 and December 31, 2018. A relatively higher proportion of these admissions occurred between 2016 and 2018. The mean age of the cohort was 4.79 ± 3.24 (median = 4.25; IQR: 2.25, 6.50) years, and the average weight was 18.45 ± 9.02 (median = 16.70; IQR: 12.50, 22.00) kg (60.78% Boys). Injuries predominantly occurred on roads (49.00%), and the most common injury mechanism was automobile-related (47.95%). The average time from injury to ICU admission was 10.86 ± 14.95 hours (median = 6.00; IQR: 4.00, 10.00). 422 (44.4%) cases

underwent emergency surgery, whereas 466 (49%) required ventilator support, with a mean ventilator assistance duration of 70.19 ± 146.62 hours (median = 14.67; IQR: 4.60, 72.50). The mean duration of ICU stay was 6.24 ± 8.01 days and the overall mean hospital stay was 16.08 ± 15.56 days. The average ISS score at ICU admission was 18.49 ± 8.86 (median = 17.00; IQR: 13.00, 25.00). After undergoing aggressive intervention, 871 (91.59%) patients improved, whereas 80 (8.41%) died.

3.2. Associated factors of trauma Severity in pediatrics

Based on univariate analysis (table 1), statistically significant associations were observed between ISS and place of residence (p = 0.021), location of the injury (p = 0.010), year of injury (p <0.001), and injury mechanism (p <0.001).

Based on multivariate stepwise regression analysis the two factors exerting the greatest influence on ISS, in descending order, were the year of injury (= 0.47; 95%CI: 0.28 – 0.65) and injury mechanism (= -0.60; 95%CI: -0.88 - -0.31). More comprehensive results are presented in Table 2.

3.3. Associated factors of mortality in pediatric trauma patients

Based on univariate analysis (table 3), statistically significant differences were observed between survived and non-survived regarding age (p <0.001), ISS score at ICU admission (p <0.001), time elapsed from injury to ICU admission (p <0.001), duration of mechanical ventilation in the ICU (p <0.001), GCS score at ICU admission (p <0.001), and the proportion of patients requiring mechanical ventilation (p <0.001).

The results of multivariate analysis (table 4) indicated that age (OR = 0.805; 95%CI: 0.70 - 0.914; p = 0.001) and GCS score at ICU admission (OR = 0.629; 95%CI: 0.53 - 0.735; p < 0.001) acted as protective factors, whereas mechanical ventilation in the ICU (OR = 7.834; 95%CI: 1.766 - 34.757; p = 0.007) and ISS score at ICU admission (OR = 1.088; 95%CI: 1.047 - 1.130; p < 0.001) served as risk factors for death.

Independent predictors of mortality in pediatric trauma patients with ages < 1 year and > 1 year are calculated and presented in Table 4, separately.

4. Discussion

This retrospective analysis clarified the epidemiological characteristics of pediatric patients with trauma admitted to our ICU in one decade.

Traumatic injury, a frequently encountered phenomenon, affects 38.5% of all children before the age of 14 years (18) . The developmental immaturity of the pediatric body increases the complexity of trauma management and contributes to the persistently high rates of disability and mortality in this age group. Trauma has emerged as a critical determinant compromising the physical health and safety of children, imposing substantial physical and psychological burdens on the affected children and their families (7).

Based on 951 pediatric trauma cases, our study's findings align with those of previous research, demonstrating a male-to-female ratio of 1.55:1 for traumatic injury, which reflects a higher incidence among boys (19, 20). As in previous literature reports on this subject (21, 22), we also found that automobile-related accidents were the predominant cause of trauma. In China, drowning, automobile accidents, suffocation, poisoning, and falls represent the top five most frequent causes of unintentional injury-related fatalities among children aged 1–4 years (23). In developed countries, automobile-related accidents similarly represent the leading cause of accidental deaths among children younger than 14 years old (24, 25). Studies have suggested that the high mortality associated with automobile injuries in Chinese children may be related to the under-use of child safety seats and seat belts in the country (26), highlighting the need for legislative efforts mandating their use (27). This study found that for every decrease in age by one year, the odds of a fatal outcome increased by 1.242 times (1/0.805); For every increase in ISS score at ICU admission by one point, the odds of a fatal outcome increased by 1.088 times. For infants under 1 year of age, an ISS score above 23 at ICU admission had the highest predictive ability for a fatal outcome after trauma. For patients over 1 year of age, an ISS score of 25 or higher at ICU admission had the highest predictive ability for a fatal outcome after trauma. Through the analysis of factors such as the Injury Severity Score (ISS) in pediatric trauma patients, it was found that the severity of trauma in children living in peri-urban areas was significantly higher compared to those living in rural areas. ISSs were higher for injuries that occurred at home, in dormitories, or on roads than for those that occurred in public places. With regard to the year of injury, the ISSs were higher from 2012 to 2018 than in 2009 to 2011, with higher scores for 2012 than for 2014 and 2016 (P < 0.05), higher scores for 2013 and 2015 than for 2016 (P < 0.05), and higher scores for 2017 and 2018 than for 2016 (P < 0.05). Regarding injury mechanism, automobile-related injuries and falls had higher ISSs than burns/scalds and sharp object injuries, with burns/scalds scores being higher than those of sharp object injuries. Other injuries also had higher scores than sharp object injuries. This indicates an upward trend in ISS over recent years, suggesting that the severity of trauma cases being treated has been increasing annually. This trend parallels advancements in technology and medicine. With enhanced medical capabilities and improved equipment, minor injuries are increasingly managed effectively at primary care facilities. Moreover, advancements in transportation ensure rapid relocation of critically injured children to major hospitals, thereby enhancing access to superior healthcare resources. Notably, our findings highlighted that trauma severity, particularly in relation to automobile accidents and falls, has escalated significantly over time, with an increasing proportion of such cases, including severe polytrauma.

Our study found that the age, time elapsed from injury to ICU admission, and GCS score at ICU admission were significantly lower in patients who died compared to those who improved. The ISS score at ICU admission and the hours of mechanical ventilation in the ICU were significantly higher in patients who died than those who improved. Patients receiving mechanical ventilation in the ICU had a 7.834 times higher risk of death compared to those not undergoing mechanical ventilation. The proportion of patients requiring mechanical ventilation was higher in patients who died compared to those who improved. These findings are consistent with existing literature reports (28-30) . Notably, Emami et al. (31), in a study involving 9959 pediatric patients with traumatic brain injury, found that children with GCS scores of ≤8 had a mortality rate that was 1.5 times higher than that of children with GCS scores of 15. Wang et al. (32) reported that a GCS score of ≤8 had a sensitivity of 48.98%, specificity of 90.94%, and accuracy of 71.20% for predicting in-hospital mortality. Furthermore, it exhibited a sensitivity of 59.21%, specificity of 98.04%, and accuracy of 89.12% for forecasting poor long-term prognosis. Our study's prognostic analysis revealed that for every one-point decrease in GCS score at ICU admission, the odds of a fatal outcome increased by 1.590 times (1/0.629). For infants under 1 year of age, the AUC for predicting death based on the GCS score at ICU admission was 0.912 (95% CI: 0.809–1.016; P < 0.001), with a specificity of 0.918, sensitivity of 0.857, and Youden's index of 0.775. The optimal cut-off value was 5.5. For children over 1 year of age, the AUC for predicting death based on the GCS score at ICU admission was 0.928 (95% CI: 0.891–0.965; P < 0.001), with a specificity of 0.894, asensitivity of 0.893, and Youden's index of 0.787. The optimal cut-off value was also 5.5.

Pediatric trauma constitutes a major public health challenge, accounting for a substantial portion of unintentional injuries. Its incidence has also been rising significantly in recent years. A comprehensive understanding of the factors influencing pediatric trauma and its outcomes can facilitate prompt assessment and treatment, aiming to minimize mortality as much as possible.

4.1. Limitations

The limitation of this study lies in its single-center, 10-year retrospective study design, which resulted in a limited perspective on the characteristics and prognoses of trauma cases, primarily reflecting the experiences of one institution. To gain a more comprehensive understanding of the current state and post-injury treatment outcomes of pediatric trauma in China, a nationwide, multicenter, prospective study encompassing diverse geographic regions with varying levels of medical care is necessary. Such an endeavor would not only elucidate contemporary epidemiology and post-trauma care across the country but also facilitate the development of targeted strategies aimed at preventing pediatric trauma and enhancing the success rates of interventions for injured children. This comprehensive approach is vital in striving to mitigate the burden of pediatric trauma and improve overall outcomes.

5. Conclusion

Automobile-related injuries represent the leading cause of trauma in children, with escalating severity scores year over year among pediatric patients admitted to the ICU with trauma injuries. Based on the findings the independent predictors of mortality of pediatric trauma patients admitted to the ICU were age, GCS score at ICU admission; mechanical ventilation in the ICU, and ISS score at ICU admission. Also, the year of injury and injury mechanism were independent predictors of trauma severity.

6. Declarations

6.1. Acknowledgments

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6.2. Funding and Support

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6.3. Conflicts of interest

The authors declare no conflicts of interest.

6.4. Data availability statement

The data can be found online at https://doi: 10.17632/7mvzk58ctj.2

6.5. Institution Review Board statement

This study adhered to the principles of the Declaration of Helsinki and was approved by the ethics committee of the children's hospital affiliated with Zhejiang University School of Medicine (Hangzhou, China; approval number: 2024-IRB-0127-P-01).

6.6. Informed consent statement

Given this report's retrospective nature and minimal risk, written informed consent was waived.

6.7. Author contributions

BYY: data collection, visualization, and manuscript writing (original version, manuscript writing - edits and revision). GLJ, YL, HL, and GCN: literature search and data collection. TLH: manuscript writing (original version, manuscript writing, edits, and revision). All authors contributed significantly to the manuscript and have read and approved its final version.

6.8. Using artificial integence chatbots

None.

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Table 1: Association between trauma severity based on injury severity scores (ISS) and bseline characteristics of pediatric trauma patients admitted to intencive care unit (n=951)

Variable	N (%)	ISS	P-value
Sex			
Male	578 (60.78)	18.70±8.65	0.364
Female	373 (39.22)	18.16±9.19	
Age group			
<6 y	673 (70.77)	18.56±9.15	0.773
6–12 y	251 (26.39)	18.42±8.22	
12–18 y	27 (2.84)	17.33±7.42	
Residence			
Urban	159 (16.72)	19.26±8.86	0.021
Suburban	180 (18.93)	19.78±8.40	
Rural	612 (64.35)	17.90±8.95a	
Resident status			
Local	759 (79.81)	18.42±9.12	0.657
Migrant worker	192 (20.19)	18.74±7.79	
Injury location			
School	7 (0.74)	13.71±7.02	0.010
Home/Dormitory	403 (42.38)	18.50±9.07	
Roadway	466 (49.00)	18.95±8.81	
Public place	66 (6.94)	15.21±7.51	
Other	9 (0.95)	21.33±6.98	
Time of injury			0.591
0–6 AM	18 (1.89)	17.50±7.53	
6–12 AM	300 (31.55)	18.93±9.32	
12–18 PM	423 (44.48)	18.51±8.53	
18–24 PM	210 (22.08)	17.89±8.97	
Year of Injury			
2009	95 (9.99)	15.28±8.23	<0.001
2010	94 (9.88)	14.83±8.33	
2011	99(10.41)	16.37±9.96	
2012	71 (7.47)	22.54±7.97	
2013	81 (8.52)	20.47±8.88	
2014	61 (6.41)	19.15±8.51	
2015	73 (7.68)	20.12±8.82	
2016	132 (13.88)	16.97±7.74	
2017	115 (12.09)	20.50±7.67	
2018	130 (13.67)	20.15±9.36	
Date of Injury			
Weekday	593 (62.36)	18.47±9.24	0.927
Weekend	358 (37.64)	18.52±8.21	
Season of injury			
Spring	258 (27.13)	19.22±8.95	0.054
Summer	256 (26.92)	19.18±9.19	
Autumn	254 (26.71)	17.85±8.28	
Winter	183 (19.24)	17.36±8.92	
Mechanism of trauma			
Traffic injury	456 (47.95)	19.08±8.84	<0.001
Fall	404 (42.48)	18.78±8.65	
Burns/Scalds	50 (5.26)	14.86±8.79	
Blast injury	6 (0.63)	15.17±9.26	
Sharp object injury	11 (1.16)	7.18±5.96	
Animal attack	2 (0.21)	8.50±6.36	
Electric shock	1 (0.11)	4.00±0.00	
Other	21 (2.21)	17.05±8.69	

Data are presented as mean ± standard deviation.

Table 2: Multivariate stepwise regression analysis of factors influencing the trauma severity in pediatric patients with trauma injuries

Independent variable	Beta ()	SE	t-value	P-value	95% CI
Constant	17.674	0.629	28.089	<0.001	16.439, 18.909
Year of injury	0.470	0.092	5.084	<0.001	0.289, 0.651
Cause of injury	-0.600	0.146	-4.114	<0.001	-0.886, -0.314

CI: confidence interval; SE: Standard error. Note: The fitted model demonstrated an F-statistic of 20.925 with P<0.001, indicating a strong statistical significance. The coefficient of determination (R^2) was 0.456, suggesting that the model explained 45.6% of the variance in the dependent variabley. The adjusted R^2, accounting for the number of predictors in the model, was 0.451.

Table 3: Associated factors of mortality in pediatric trauma patients admitted to intensive care unit

Variables	Non-survived (n=80)	Survived (n=871)	P-value
Sex			
Male	45 (56.2)	533 (61.2)	0.386
Female	35 (43.8)	338 (38.8)	
Age (year)			
Mean ± SD	3.44 ± 2.65	4.91 ± 3.26	<0.001
Injury site			
Multiple trauma	29 (36.3)	363 (41.7)	0.345
Single trauma	51 (63.7)	508 (58.3)	
Mechanism of trauma			
Traffic accident	44 (55)	412 (47.3)	0.133
Fall	33 (41.3)	371 (42.6)	
Other	3 (3.7)	88 (10.1)	
ISS Score at ICU admission			
Mean ± SD	30.19 ± 10.60	17.41 ± 7.86	<0.001
Injury to the ICU admission (hour)			
Mean ± SD	6.74 ± 8.35	11.24 ± 15.36	<0.001
Emergency surgery			
Yes	34 (42.5)	388 (44.5)	0.724
No	46 (57.5)	483 (55.5)	
Mechanical ventilation in ICU			
Yes	78 (97.5)	388 (44.5)	<0.001
No	2 (2.5)	483 (55.5)	
Duration mechanical ventilation in the ICU (hour)			
Mean ± SD	161.44 ± 274.43	22.50 ± 65.26	<0.001
Duration of ICU admission (day)			
Mean ± SD	8.13 ± 12.10	6.06 ± 7.52	0.138
GCS score at ICU admission			
Mean ± SD	4.35 ± 2.54	10.91 ± 3.73	<0.001

Data are presented as mean ± standard deviation (SD) or number (%). ISS: Injury Severity Score; ICU, intensive care unit; GCS, Glasgow Coma Scale.

Table 4: Multivariate analysis of mortality associated factors in pediatric trauma patients admitted to intensive care unit

Variable	β	Wald	OR	95%CI	P
Overall					
Age (year)	-0.217	11.218	0.805	0.709-0.914	0.001
ISS at ICU admission	0.84	18.455	1.088	1.047-1.130	<0.001
Injury to ICU admission	-0.12	0.528	0.988	0.958-1.020	0.467
Duration mechanical ventilation	0.001	2.191	1.001	1.000-1.003	0.139
GCS score at ICU	-0.464	34.075	0.629	0.538-0.735	<0.001
Ventilation in ICU					
Yes	2.058	7.333	7.834	1.766-34.757	0.007
No	(Ref)				
Trauma patients(age ≤1 year)					
Age (month)	0.498	3.579	1.645	0.982-2.755	0.059
ISS at ICU admission	0.363	7.220	1.438	1.103-1.874	0.007
Injury to ICU admission	-0.017	0.056	0.984	0.857-1.129	0.814
Duration mechanical ventilation	0.020	1.125	1.020	0.983-1.059	0.289
GCS score at ICU	-0.463	5.507	0.630	0.428-0.927	0.019
Trauma patients (age >1 year)					
Age (y)	-0.171	5.985	0.843	0.735-0.967	0.014
ISS at ICU admission	0.080	15.291	1.083	1.041-1.127	<0.001
Injury to ICU admission	-0.007	0.184	0.993	0.962-1.025	0.668
Duration mechanical ventilation	0.002	2.474	1.002	1.000-1.003	0.116
GCS score at ICU	-0.493	29.408	0.611	0.511-0.730	<0.001
Ventilation in ICU					
Yes	1.772	5.328	5.882	1.307-26.479	0.021
No	Ref				

OR: odds ratio; CI: confidence interval; ISS: Injury Severity Score; ICU: intensive care unit; GCS: Glasgow Coma Scale.