The Functional Outcome of Patients Following Spinal Injury in Asia Metropolitans: Does the Prehospital Spine Immobilization Matter?

Hsuan An Chen

Far Eastern Memorial Hospital

Shuo Ting Hsu

Far Eastern Memorial Hospital

Sang Do Shin

Seoul National University College of Medicine and Hospital

Sabariah Faizah Jamaluddin

Universiti Teknologi MARA

Do Ngoc Son

Bach Mai Hospital

Ki Jeong Hong

Seoul National University College of Medicine and Hospital

Hideharu Tanaka

Graduate School of Kokushikan University

Jen Tang Sun

Far Eastern Memorial Hospital

Wen-Chu Chiang (✉ drchiang.tw@gmail.com)

National Taiwan University Hospital

Research Article

Keywords: Patients, Spinal Injury, Prehospital, Immobilization

Posted Date: July 27th, 2021

DOI: <https://doi.org/10.21203/rs.3.rs-724919/v1>

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Abstract

Prehospital spinal immobilization is a widely used procedure in the emergency medical service (EMS) system worldwide, while the incidence of patients with spinal injury (SI) is relatively low, and unnecessary prehospital spinal immobilization is associated with patient complications. This study aimed to determine the association between prehospital spine immobilization and favorable functional outcomes at hospital discharge among trauma patients with SI. We conducted a retrospective cohort study using the Pan-Asia Trauma Outcomes Study (PATOS) registry data from January 1, 2016, to November 30, 2018. A total of 759 patients with SI were enrolled from 43,752 trauma patients in the PATOS registry during the study period. The subjects had a median age of 58 years (Q1–Q3, 41–72), and 438 (57.7%) patients had prehospital spine immobilization. Overall, prehospital spinal immobilization was not associated with favorable functional outcomes at discharge in multivariable logistic regression (aOR, 1.06; 95%CI 0.62–1.81, $p = 0.826$). However, in the subgroup of cervical SI, prehospital spinal immobilization was associated with favorable functional outcomes at discharge (aOR, 3.14; 95%CI 1.04–9.50; $p = 0.043$). Therefore, we suggest that paramedics should be more careful when determining cervical SI and using prehospital immobilization.

Introduction

Patients with spinal injuries (SIs) following trauma are at risk of spinal cord injuries (SCIs) with severe neurological consequences and disability in life, which are estimated in approximately 20% of these cases¹. However, the incidence of traumatic SCI differs from region to region, with a relatively low incidence of 16 per million in Western Europe to 40 per million in the United States². The incidence of SI in the trauma population also varied from 4.58% in China to all trauma patients³ and 9.6% in Europe in patients following major trauma⁴, while some studies reported only 1–2% of all trauma patients⁵.

Despite the relatively low incidence of SI and SCI, prehospital spinal immobilization has been widely adopted worldwide as well as in trauma courses, such as prehospital trauma life support (PHTLS) and advanced trauma life support (ATLS)^{6,7}. It aims to minimize further movement of the spine and reduce the risk of secondary injury, but the procedure lacks high-quality evidence of clear benefits in decreasing disability^{8,9} and is associated with complications such as respiratory restriction^{10,11}, elevated intracranial pressure^{12,13}, pressure ulcers¹⁴ and changing the results of physical examination¹⁵ while patients are immobilized. In addition, previous studies also revealed that prehospital immobilization may be associated with higher mortality in patients with penetrating trauma and gun-shot wounds^{16–18}.

Due to the growing concerns regarding prehospital spinal immobilization, this study aimed to determine the association between prehospital spinal immobilization and favorable functional outcomes at hospital discharge among adult trauma patients with SI.

Methods

Study design and setting

We conducted a retrospective cohort study using a prospectively collected database from the Pan-Asia Trauma Outcomes Study (PATOS), which was a cross-national trauma registry network initiated in 2015 and consists of 33 participating sites from 14 Asian countries, including Australia, Hong Kong, India, Indonesia, Japan, Korea, Malaysia, Philippines, Singapore, Sri Lanka, Taiwan, Thailand, the United Arab Emirates, and Vietnam. Urban areas are covered by all countries¹⁹. The variables of PATOS include demographics, injury epidemiology, prehospital care, emergency department (ED) and hospital care, injury severity, and clinical outcomes²⁰. The PATOS Trauma Database was characterized as an emergency medical service (EMS)-based registry. Participation in the PATOS registry was voluntary. Patient's data were recorded in the registry if they were sent to the participating hospitals due to trauma, either from the scene or via interhospital transport.

Study population

We analyzed patients with PATOS from January 1, 2016, to November 30, 2018. Eligible patients were transported by EMS, aged >16 years, and with SIs. SI was defined as any spinal fracture, dislocation, subluxation, or traumatic disc rupture with or without SCI. The diagnosis was selected using ICD-9 (other paralytic syndromes 344.0-344.9; fracture of vertebral column without mention of SCI 805.0-805.5; fracture of the vertebral column with SCI 806.0-806.6; dislocation of vertebra 839.4; SCI without evidence of spinal bone injury 952.0-952.9) or ICD-10 (fracture of vertebra S12.0-S12.9, S22.0, S32.0, S32.9; dislocation, subluxation of vertebrae, traumatic rupture of intervertebral disc S13.0-S13.1, S23.0-S23.1, S33.0-S33.1; injury of nerves and spinal cord S14.0-S14.9, S24.0-S24.2, S34.0-S34.2) based on the registry data, we excluded patients with pre-existing disability (defined as Glasgow Outcome Score [GOS] <4 before the injury), traumatic brain injury (TBI) (defined as traumatic cerebral edema, diffuse/focal TBI, epidural hemorrhage, traumatic subdural hemorrhage, traumatic subarachnoid hemorrhage using ICD-9 854.0, 851.0-852.5; ICD-10 S06.1-S06.9), incomplete data on immobilization, Injury Severity Score (ISS), Revised Trauma Score (RTS) at the ED, functional outcome at discharge or prehospital time interval. We excluded patients with TBI because the prevalence of concomitant TBI in patients with an SI can be as high as 32.5%²¹, and we could not differentiate whether the disability resulted from TBI or SI.

Definition of exposure

The key exposures in our study were prehospital immobilization, which was defined as the neck collar and/or backboard used. The basic characteristics of the patients in our study included country, age, sex, mechanism of injury (traffic, fall, others), location of SI (cervical, thoracic, or lumbar spine), and torso injury. Torso injury was defined as injury involving the chest or abdomen, including fractures of the clavicle, rib, pelvis, traumatic pneumothorax, hemothorax, intra-abdominal bleeding, laceration, or contusion of the spleen, liver, or bowel. Data on prehospital management, including spinal immobilization, rescue airway (supraglottic airway or endotracheal tube), the establishment of fluid access either by intravenous line (IV) or by intraosseous line (IO), and scene-to-hospital time (S to H time) were collected. Because one of the major contributing countries (Korea) mostly reported the S to H time rather than transport time, we used S to H time as variables to maximize the valid value. We used the RTS and ISS as indices of trauma severity. RTS is a physiological triage score using the Glasgow Coma Scale (GCS), systolic blood pressure (SBP), and respiratory rate (RR). The RTS formula was as follows: $RTS = (GCS \text{ score coded} \times 0.9368) + (SBP \text{ coded} \times 0.7326) + (RR \text{ coded} \times 0.2908)$ ²². ISS was calculated by summing the square of the three highest Abbreviated Injury Scale scores for injuries to different body regions²³. We divided the ISS score into three groups: <9, minor injury; 9-15 defined as moderate injury; and ≥ 16 , severe injury^{24,25}. We also collected data from patients who had undergone spine surgery or surgery of other body regions except for the spine. Missing data of the variables were excluded.

Outcome measurements

The primary outcome was the modified Rankin Scale (mRS) score at discharge. MRS was used to evaluate the functional outcome in patients with stroke at first²⁶ and was then applied to measure the disability caused by TBI and general trauma²⁷⁻³⁰. No significant disability to moderate disability (mRS 0-3) was defined as favorable functional outcome, and moderately severe disability to death (mRS 4-6) was defined as poor functional outcomes³¹. Subgroup analyses were performed in different subgroups of age (<65 and ≥ 65 years), RTS (<7 and ≥ 7), ISS (<9, ≥ 9), and the location of SI (cervical, thoracic, and lumbar regions). We used 65 years old as the cut-off value because it represents the most commonly accepted age to consider a patient as an elderly patient and was used according to the guidelines of the Eastern Association for the Surgery of Trauma^{32,33}. A score of 7 as the cut-off point in RTS and 9 as the cut-off point in ISS were used in previous studies for major trauma^{25,34,35}.

Statistical methods

Continuous variables are reported as mean or median (Q1-Q3), as appropriate. Dichotomous and categorical variables are presented as numbers (percentages). Continuous variables were compared using the Mann-Whitney U test. Categorical and nominal variables were compared using Pearson's chi-square test or Fisher's exact test. We examined the association between prehospital spinal immobilization and favorable functional outcomes using univariate logistic regression and multivariable logistic regression. Variables with $p < 0.05$ on univariable logistic regression and the major variable (prehospital spinal immobilization) were selected for multivariable logistic regression analysis using the forced entry method. For subgroup analyses, we also conducted multiple logistic regression using the forced entry method for all variables. Statistical analysis was performed using SPSS version 25.0 (IBM, Armonk, NY, USA). All tests were two-sided, and a p-value of less than 0.05 was considered statistically significant.

Ethics approval and consent to participate

The PATOS collaboration was approved by the Institutional Review Board of the National Taiwan University Hospital and Far Eastern Memorial Hospital. This study was conducted in accordance with the Declaration of Helsinki (as revised in 2013) and the study proposal and methods were approved by the PATOS Taipei Meeting. The data were anonymized before being released to the authors in 2019. Institutional Review Board of Far Eastern Memorial Hospital waived the need for Informed consent due to the retrospective nature of this study.

Results

Characteristics of study objects

From January 1, 2016, to November 30, 2018, a total of 1,573 cases with SIs were extracted from the PATOS registry of 43,752 EMS-transported trauma patients (3.5% of all cases) using ICD-9 or ICD-10. We further excluded patients aged <16 years ($n = 30$), pre-existing disability (GOS 1-3) before the injury ($n = 274$), TBI ($n = 136$), and incomplete data ($n = 374$). The remaining 759 adult patients diagnosed with SI were included in the study, and 438 (57.7%) patients had prehospital spine immobilization. Figure 1 shows a detailed flow diagram of the patients enrolled in the final analysis.

The demographics of the 759 patients with prehospital spinal immobilization are shown in Table 1. The study cohort consisted of patients from four countries, including Korea, Malaysia, Japan, and Vietnam. Korea and Malaysia accounted for 97.1% of the study group. Injury mainly resulted from traffic accidents and falling accidents, and all patients had blunt injuries. The combination of cervical SI and thoracic or lumbar SI was only 3.1% ($n = 24$).

Compared to the patients in the non-immobilized group, the patients in the immobilized group were younger (54 vs. 65), had a higher percentage of males (61.4% vs. 47.0%), a higher percentage of traffic accidents (52.3% vs. 27.7%), a higher percentage of patients who received prehospital fluid management (9.8% vs. 1.9%), higher percentage of cervical SI (33.6% vs. 16.8%), lower percentage of lumbar SI (47.9% vs. 59.5%), higher percentage of torso injury (30.6% vs. 11.8%), higher percentage of RTS <7 (5% vs. 2.2%), higher percentage of ISS score 9–15 (31.3% vs. 16.5%) and ≥ 16 (12.1% vs. 8.7%), higher percentage of patients who underwent spine surgery (11.4% vs. 3.4%), and other operations (16.7% vs. 7.5%).

Association between prehospital spinal immobilization and favorable functional outcome

For the primary outcome of the association between prehospital spinal immobilization and favorable functional outcome, the demographics and the results of univariable and multivariable logistic regression are shown in Table 2. In univariable logistic regression, prehospital spinal immobilization was not significantly associated with favorable functional outcomes (OR, 0.66; 95%CI 0.42-1.02; $p = 0.061$). Different countries, age, sex, prehospital fluid management, lumbar SI, torso injury, RTS, ISS 9–15, and ISS ≥ 16 was significantly associated with favorable functional outcomes in univariable logistic regression and were selected as adjusting confounding factors in further multivariable logistic regression. In multivariable logistic regression, prehospital spinal immobilization was not associated with favorable functional outcomes (aOR, 1.06; 95%CI 0.62-1.81; $p = 0.826$). Different countries (compared to Korea) (Malaysia aOR, 0.37; 95%CI 0.20-0.71; $p = 0.002$),

prehospital fluid management (aOR, 0.39; 95%CI 0.19-0.84), ISS 9–15 (aOR, 0.41; 95%CI 0.24-0.72; $p = 0.002$), ISS ≥ 16 (aOR, 0.35; 95%CI 0.17-0.72; $p = 0.004$), and patients who underwent spine surgery (aOR, 0.21; 95%CI 0.11-0.41; $p < 0.001$) were associated with worse functional outcomes. Only RTS ≥ 7 was associated with favorable functional outcomes (aOR, 3.41; 95%CI 1.41-8.25; $p = 0.007$).

Subgroup analysis

In the subgroup analysis (Figure 2), we found that prehospital spinal immobilization was associated with favorable functional outcomes in the subgroup of cervical SI (aOR, 3.14; 95%CI 1.04-9.50; $p = 0.043$), but not in the subgroup ISS < 9 , ISS ≥ 9 , RTS ≥ 7 , thoracic SI, and lumbar SI. Unfortunately, multivariable logistic regression could not be performed due to the limited number of patients in subgroup RTS < 7 .

Discussion

In this cross-national retrospective cohort study from January 1, 2016, to November 30, 2018, we found that prehospital spinal immobilization was not associated with favorable functional outcomes at discharge in all EMS-transported patients with SI; however, in the subgroup of cervical SI, the procedure still mattered. There was a significant association between prehospital spinal immobilization and favorable functional outcomes at discharge. Our study has several strengths. First, this was a cross-national study in Asia with different EMS systems. Hence, the results may be applicable to other Asian populations. Second, we excluded preexisting disability before injury and TBI to minimize the effect on functional outcome at discharge and to focus more on the impact of SI.

The benefit of spinal immobilization came from indirect and low evidence that numerous studies found that delayed diagnosis of SI without immobilization was correlated with worse disability³⁶⁻³⁸. Toscana et al.³⁸ conducted a case series of 123 patients with blunt SI and found that 32 (26%) patients had major neurological deterioration between the time of injury and the time of admission. Of these 32 patients, 19 (59%) had no immobilization, suggesting that neurological deterioration resulted from not being immobilized. Meanwhile, Hauswald et al.³⁹ retrospectively reviewed patients with traumatic SI from the USA and Malaysia, where the former had prehospital spinal immobilization, but the latter did not have prehospital spinal immobilization in all patients. The results revealed that non-immobilized Malaysian patients had a less neurologic disability (OR, 2.03; 95%CI 1.03–3.99; $p = 0.04$). However, the study was criticized by some points, such as patients who died in the scene or transportation were excluded, no matching of the patient's injury severity, and relatively small sample size. In our study, we did not exclude patients with traumatic out-of-hospital cardiac arrest, and we performed a subgroup analysis to match the injury severity of patients.

In the subgroup analysis of our study, there was a statistically significant association between prehospital spinal immobilization and favorable functional outcome when limited to patients with cervical SI. Excluding patients with TBI may be a cause. The prevalence of concomitant TBI in patients with an SI was 32.5% (95%CI 10.8–59.3%) and 40.4% (95%CI 33.0–48.0%) in patients with cervical SI²¹. Severe TBI can cause severe functional disability or death; approximately 38% of patients die⁴⁰ and, as estimated, 43% are discharged with long-term disability⁴¹. Moreover, spinal immobilization could also increase intracranial cerebral pressure in immobilized patients, which could worsen the situation of TBI¹². Excluding patients with concomitant TBI decreased the influence of brain injury and helped us focus on the effects of SCI and SI.

The incidence of SI in our study was 3.5% in all EMS-transported trauma patients, which was similar to a previous study from China with an incidence of 4.58% in the trauma population³. The percentage of patients with cervical SI and other locations of SI were also similar to those reported in previous studies^{3,42}, indicating the generalizability of our findings. The incidence data for Europe and Canada were relatively high, at 9.6% and 23.2%, respectively^{4,42}, which may be due to the study population with polytrauma and higher severity in their studies. The leading causes of SI were falls (47.3%) and traffic accidents (41.9%), which is consistent with previous studies^{2,43}. The rate of cervical SI combined with thoracic or lumbar SI

in our study was 3.1%, which was lower than previous studies (approximately 10%)^{4,6}. Patients with lower trauma severity in our study may have been the cause.

In patients in the immobilized group, statistically significant higher trauma severity (ISS, RTS), higher percentage of combined torso injury, prehospital fluid management, and SI were noted than non-immobilized groups. It is reasonable that severely injured patients would receive more treatment at the scene. Subgroup analysis using ISS and RTS was performed to reduce the impact of injury severity, and the association between favorable functional outcome and prehospital spinal immobilization was not significant in the subgroup with $ISS < 9$, $ISS \geq 9$, and $RTS \geq 7$. The scene-to-hospital time was not significantly different between the immobilized and non-immobilized groups, although the immobilized group received more treatment out of the hospital. This might be due to the familiarity of the procedure from paramedics, and only 42% (N = 184) of patients received full spine immobilization in the immobilized group.

Limitation

There are some limitations to this study. First, this retrospective study had to address the problem of missing data. Some countries did not record some confounding variables, and we had to exclude them from the analysis, which may have caused selection bias. Although we included many variables in the logistic regression analysis, other unknown factors could influence the functional outcomes, such as limited prehospital information from EMS, the quality of each EMS team, bystander management of the patients, the quality of in-hospital care, and subsequent rehabilitation programs. These data cannot be included in our analysis because of incomplete data or non-recording of the variables in the registry. Second, the registry data of PATOS were voluntary and could not be considered a representative sample of the included countries. Third, the sample size was relatively small. However, considering the relatively low incidence rate of SI and SCI, we believe that these findings are still informative to the knowledge gap.

Conclusion

Prehospital spinal immobilization was not associated with favorable functional outcomes in traumatic patients with SI; however, subgroup analysis revealed that it may be beneficial for patients with cervical SI without TBI. Based on our findings, we suggest that paramedics should be more judicious when determining the cervical SI and use prehospital immobilization, and prospective trials may be needed in the future.

Declarations

Acknowledgements

The authors acknowledge all participating PATOS sites for excellent collaboration, as well as the data quality assurance of the PATOS coordination center at Seoul National University Hospital, to improve prehospital and in-hospital care for trauma patients in Asia. The authors also like to thank the staff, Dr. Chin-Hao Chang, of the National Taiwan University Hospital Statistical Consulting Unit for help in statistical consultation.

Authors' contributions

J.T.S. designed the study. S.D.S., S.F.J., D.N.S., K.J.H. and H.T. collected and investigated data source. H.A.C., S.T.H., J.T.S. and W.C.C. carried out analysis and interpretation. H.A.C. and W.C.C. performed the statistical analysis. H.A.C. and S.T.H. drafted the paper. J.T.S. and W.C.C. drafted and supervised the study. All authors reviewed the manuscript. Jen Tang Sun and Wen Chu Chiang take responsibility for the paper.

Competing interests

There are no competing interests to declare.

Data availability

The data that support the findings of this study are available from Pan-Asia Trauma Outcomes Study (PATOS) but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data are however available from the authors upon reasonable request and with permission of PATOS. For more detailed information of PATOS, following website is available, <http://lems.re.kr/eng/patos-research/>.

Funding

This study was funded by the Taiwan Ministry of Science and Technology (MOST 108-2314-B-002-130-MY3 and MOST 105-2314-B-002-200-MY3 and MOST 109-2314-B-002 -154-MY2). The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

PATOS Clinical Research Network

Participating Nation Investigators: T.V. Ramakrishnan (India), Sabariah Faiwah Jamaluddin (Malaysia), Hideharu Tanaka (Japan), Bernadett Velasco (Philippines), Ki Jeong Hong (South Korea), Jen Tang Sun (Taiwan), Pairoj Khruengkarnchana (Thailand), Saleh Fares LLC (United Arab Emirates), Do Ngoc Son (Vietnam)

Participating Site Investigators: Ramana Rao (GVK EMRI, India), George P. Abraham (Indian Institute of Emergency Medical Services, India), T.V. Ramakrishnan (Sri Ramachandra Medical Center, India), Sabariah Faiwah Jamaluddin (Sungai Buloh Hospital, Malaysia), Mohd Amin Bin Mohidin (Sultanah Aminah Hospital, Malaysia), Al-Hilmi Saim (Seri Manjung Hospital, Malaysia), Lim Chee Kean (Pulau Pinang Hospital, Malaysia), Cecilia Anthonysamy (Serdang Hospital, Malaysia), Shah Jahan Din Mohd Yssof (Kuala Lumpur Hospital, Malaysia), Kang Wen Ji (Sarikei Hospital, Malaysia), Cheah Phee Kheng (Sabah Women and Childrens Hospital, Malaysia), Shamila bt Mohamad Ali (Ampang Hospital, Malaysia), Periyannayagi Ramanathan (Kajang Hospital, Malaysia), Chia Boon Yang (Miri Hospital, Malaysia), Hon Woei Chia (Sarawak General Hospital, Malaysia), Hafidahwati binti Hamad (Queen Elizabeth II Hospital, Malaysia), Samsu Ambia Ismail (Teluk Intan Hospital, Malaysia), Wan Rasydan B. Wan Abdullah (Raja Perempuan Zainab II Hospital, Malaysia), Hideharu Tanaka (Kokushikan University, Japan), Akio Kimura (National Center for Global Health and Medicine Hospital, Japan), Bernadett Velasco (East Avenue Medical Center, Philippines), Carlos D. Gundran (Philippine College of Emergency Medicine, Philippines), Pauline Convocar (Southern Philippines Medical Centre, Philippines), Nerissa G. Sabarre (Pasig City General Hospital, Philippines), Patrick Joseph Tiglao (Corazon Locsin Montelibano Memorial Regional Hospital, Philippines), Ki Jeong Hong (Seoul National University Hospital, South Korea), Kyoung Jun Song (Boramae Medical Center, South Korea), Joo Jeong (Seoul National University Bundang Hospital, South Korea), Sung Woo Moon and Joo-yeong Kim (Korea University Ansan Hospital, South Korea), Won Chul Cha (Samsung Medical Center, South Korea), Seung Chul Lee (Dongguk University Ilsan Hospital, South Korea), Jae Yun Ahn (Kyungpook National University Hospital, South Korea), Kang Hyeon Lee (Wonju Severance Christian Hospital, South Korea), Seok Ran Yeom (Pusan National University Hospital, South Korea), Hyeon Ho Ryu (Chonnam National University Hospital, South Korea), Su Jin Kim (Korea University Anam Hospital, South Korea), Sang Chul Kim (Chungbuk National University Hospital, South Korea), Lin-Chen Chiang (National Taiwan University Hospital, Taiwan), Jen Tang Sun (Far Eastern Memorial Hospital, Taiwan), Ruei-Fang Wang (Shin Kong Wu Ho-Su Memorial Hospital, Taiwan), Shang-Lin Hsieh (Mackay Memorial Hospital, Taiwan), Wei-Fong Kao (Taipei City Hospital, Taiwan), Sattha Riyapan (Faculty of Medicine Siriraj Hospital, Thailand), Parinya Tianwibool (Faculty of Medicine Chiangmai University, Thailand), Phudit Buaprasert (Faculty of medicine Vajira hospital, Navamindradhiraj University, Thailand), Osaree Akaraborworn (Prince of Songkla University, Thailand), Omer Ahmed Al Sakaf (Dubai Cooperation for Ambulance Services, United Arab Emirates), Saleh Fares LLC (National Ambulance, United Arab Emirates), Le Bao Huy (Thong Nhat Hospital, Vietnam), Do Ngoc Son (Bach Mai Hospital, Vietnam), Nguyen Van Dai (Viet Tiep Hospital, Vietnam)

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Tables

Table 1
Demographics of immobilized and non-immobilized patients

		Total N = 759	Immobilized N = 438	Non-immobilized N = 321	P-value
Country N (%)	KR	614 (80.9)	362 (82.6)	252 (78.5)	0.077
	MY	123 (16.2)	74 (16.9)	49 (15.3)	
	OTH*	22 (2.9)	2 (0.5)	20 (6.2)	
Age median (Q1-Q3)		58 (41–72)	54 (38–67)	65 (49–76)	< 0.001
Sex N (%)	Female	339 (44.7)	169 (38.6)	170 (53.0)	< 0.001
	Male	420 (55.3)	269 (61.4)	151 (47.0)	
S to H time (median, Q1-Q3)		22 (15–32)	22 (15–33)	22 (15–31)	0.816
Mechanism	Traffic	318 (41.9)	229 (52.3)	89 (27.7)	< 0.001
N (%)	Fall	359 (47.3)	177 (40.4)	182 (56.7)	
	Others#	82 (10.8)	32 (7.3)	50 (15.6)	
Prehospital management (no vs. yes)	Fluid (IV, IO)	49 (6.5)	43 (9.8)	6 (1.9)	< 0.001
Location of SI N (%) (no vs. yes)	Cervical SI	201 (26.4)	147 (33.6)	54 (16.8)	< 0.001
	Thoracic SI	197 (26)	113 (25.8)	84 (26.2)	0.909
	Lumbar SI	401 (52.8)	210 (47.9)	191 (59.5)	0.002
	C + T/L	24 (3.1)	22 (5.0)	2 (0.6)	0.001
Torso injury N (%) (no vs. yes)		172 (22.7)	134 (30.6)	38 (11.8)	< 0.001
RTS N (%)	< 7	29 (3.8)	22 (5.0)	7 (2.2)	0.044
	≥ 7	730 (96.2)	416 (95.0)	314 (97.8)	
ISS N (%)	< 9	488 (64.3)	248 (56.6)	240 (74.8)	< 0.001
	9–15	190 (25.0)	137 (31.3)	53 (16.5)	
	≥ 16	81 (10.7)	53 (12.1)	28 (8.7)	
Operation N (%) (no vs. yes)	Spine	61 (8.0)	50 (11.4)	11 (3.4)	< 0.001
	Others!	97 (12.8)	73 (16.7)	24 (7.5)	< 0.001
Favorable functional outcome N (%)	Yes	658 (86.7)	371 (84.7)	287 (89.4)	0.059
	No	101 (13.3)	67 (15.3)	34 (10.6)	
Death N (%) (no vs. yes)		7 (0.9)	3 (0.7)	4 (1.2)	0.424
KR, Korea; MY, Malaysia; OTH, others; S to H time, scene to hospital time; SI, spinal injury; RTS, revised trauma score; ISS, Injury Severity Score.					
*Others: Japan and Vietnam.					
#Others: hit by person or object, choking or hanging, drowning, physical overexertion, another mechanism of injury					
!Other operations: One patient could have undergone several operations at the same hospital stay.					

Table 2

Demographic, univariable, and multivariable-adjusted logistic regression of favorable and unfavorable functional outcomes in patients

		Favorable functional outcome N = 658	Unfavorable functional outcome N = 101	Univariable OR (95%CI)	Univariable P-value	Multivariable OR (95%CI)	Multivariable P-value
Country N (%)	KR	551 (83.7)	63 (62.4)	ref	ref	ref	ref
	MY	89 (13.5)	34 (33.7)	0.30 (0.19–0.48)	< 0.001	0.37 (0.20–0.71)	0.002
	OTH*	18 (2.7)	4 (4.0)	0.52 (0.17–1.57)	0.242	0.57 (0.16–1.99)	0.376
Age (median, Q1-Q3)		59 (43–72.3)	52 (34.5–65)	1.02 (1.01–1.03)	0.002	1.00 (0.98–1.01)	0.777
Sex N (%)	female	308 (46.8)	31 (30.7)	ref	ref	ref	ref
	male	350 (53.2)	70 (69.3)	0.50 (0.32–0.79)	0.003	0.76 (0.46–1.27)	0.296
S to H time (median, Q1- Q3)		22 (15.8–31)	23 (14–34.5)	1.00 (0.99–1.01)	0.992		
Mechanism	traffic	265 (40.3)	53 (52.5)	Ref	ref		
N (%)	Fall	319 (48.5)	40 (39.6)	1.6 (1.03–2.48)	0.38		
	Others#	74 (11.2)	8 (7.9)	1.85 (0.84–4.06)	0.13		
Prehospital management N (%) (no vs. yes)	Fluid (IV, IO)	29 (4.4)	20 (19.8)	5.36 (2.90–9.91)	< 0.001	0.39 (0.19–0.84)	0.016
Location of SI N (%) (no vs. yes)	Cervical SI	168 (25.5)	33 (32.7)	0.69 (0.41–1.16)	0.158		
	Thoracic SI	173 (26.3)	24 (23.8)	1.24 (0.67–2.31)	0.493		
	Lumbar SI	357 (54.3)	44 (43.6)	1.87 (1.17–2.99)	0.009	1.07 (0.67–1.72)	0.772
	C + TLS	21 (3.2)	3 (3.0)	1.08 (0.32–3.68)	0.906		

KR, Korea; MY, Malaysia; OTH, others; S to H time, scene to hospital time; SI, spinal injury; RTS, revised trauma score; ISS, Injury Severity Score.

*Others: Japan and Vietnam.

#Others: hit by person or objects, choking or hanging, drowning, physical overexertion, another mechanism of injury

!Other operations: One patient could have undergone several operations during the same hospital stay.

		Favorable functional outcome N = 658	Unfavorable functional outcome N = 101	Univariable OR (95%CI)	Univariable P-value	Multivariable OR (95%CI)	Multivariable P-value
Torso injury N (%) (no vs. yes)		137 (20.8)	35 (34.7)	0.50 (0.32–0.78)	0.002	1.13 (0.63–2.02)	0.683
Immobilization	no	287 (43.6)	34 (33.7)	ref	ref	ref	ref
N (%)	yes	371 (56.4)	67 (67.3)	0.66 (0.42–1.02)	0.061	1.06 (0.62–1.81)	0.826
RTS N (%)	< 7	17 (2.6)	12 (11.9)	ref	ref	ref	ref
	≥ 7	641 (97.4)	89 (88.1)	5.08 (2.35–11.00)	< 0.001	3.41 (1.41–8.25)	0.007
ISS N (%)	< 9	450 (68.4)	38 (37.6)	ref	ref	ref	ref
	9–15	150 (22.8)	40 (39.6)	0.32 (0.20–0.51)	< 0.001	0.41 (0.24–0.72)	0.002
	≥ 16	58 (8.8)	23 (22.8)	0.21 (0.12–0.38)	< 0.001	0.35 (0.17–0.72)	0.004
Operation N (%) (no vs. yes)	Spine	39 (5.9)	22 (21.8)	0.23 (0.13–0.40)	< 0.001	0.21 (0.11–0.41)	< 0.001
	Others!	75 (11.4)	22 (21.8)	0.46 (0.27–0.79)	< 0.001	0.89 (0.47–1.68)	0.715
KR, Korea; MY, Malaysia; OTH, others; S to H time, scene to hospital time; SI, spinal injury; RTS, revised trauma score; ISS, Injury Severity Score.							
*Others: Japan and Vietnam.							
#Others: hit by person or objects, choking or hanging, drowning, physical overexertion, another mechanism of injury							
!Other operations: One patient could have undergone several operations during the same hospital stay.							

Figures

Figure 1

Flow diagram of patients included in our study GOS, Glasgow outcome scale; mRS, modified Rankin Scale; RTS, revised trauma score; StoH time, Scene-to-hospital time *Patients with spinal injury were defined as meeting the diagnosis of ICD-9 or 10 described in the methods.

Figure 2

Subgroup analysis for favorable neurologic outcome, ISS<9, ISS $\geq$ 9, age $\geq$ 65, age<65, adjusted multiple logistic regression aOR, adjusted odds ratio; SI, spinal injury. *All subgroups except RTS <7 were adjusted by country, age, sex, scene-to-hospital time, mechanism, prehospital fluid management, cervical spinal injury, thoracic spinal injury, lumbar spinal injury, torso injury, revised trauma score, ISS, received spine operation, and received other operations. **Due to the small subgroup size, multivariable logistic regression was not applicable.