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Association between spinal immobilization and survival at discharge for on-scene blunt traumatic cardiac arrest: A nationwide retrospective cohort study

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ABSTRACT

Introduction: Spinal immobilization has been indicated for all blunt trauma patients suspected of having cervical spine injury. However, for traumatic cardiac arrest (TCA) patients, rapid transportation without compromising potentially reversible causes is necessary. Our objective was to investigate the temporal trend of spinal immobilization for TCA patients and to examine the association between spinal immobilization and survival.
Methods: We conducted a retrospective cohort study using the Japan Trauma Data Bank 2004–2015 registry data. Our study population consisted of adult blunt TCA patients encountered at the scene of a trauma. The primary outcome was the survival proportion at hospital discharge, and the secondary outcome was the proportion achieving return of spontaneous circulation (ROSC). We examined the association between spinal immobilization and these outcomes using a logistic regression model based on imputed data sets with the multiple imputation method to account for missing data.
Results: Among 4313 patients who met the inclusion criteria, 3307 (76.7%) were immobilized. The proportion of patients that underwent spinal immobilization gradually decreased from 82.7% in 2004–2006 to 74.0% in 2013–2015. 1.0% of immobilized and 0.9% of non-immobilized patients had severe cervical spine injury. Spinal immobilization was significantly associated with lower survival at discharge (odds ratio [OR], 0.64; 95% confidence interval [CI], 0.42 to 0.98) and ROSC by admission (OR, 0.48; 95%CI, 0.27 to 0.87). There was no significant sub-group difference of the association between spinal immobilization and survival at discharge by patients with or without cervical spine injury (p for interaction 0.73).
Conclusion: Spinal immobilization is widely used even for blunt TCA patients, even though it is associated with a lower rate of survival at discharge and ROSC by admission. According to these results, we suggest that spinal immobilization should not be routinely recommended for all blunt TCA patients.

Introduction

Spinal immobilization has conventionally been regarded as an essential procedure for securing a potentially injured cervical spine in all trauma victims, including traumatic cardiac arrest (TCA) patients [1,2]. However, little evidence supports this practice [3–5], and a number of associated disadvantages have also been reported. [2,6,7] Indeed, a previous study showed that spinal immobilization had a harmful effect on survival among penetrating trauma patients. [8] While spinal immobilization is still recommended for select blunt trauma patients with neurological deficits, such as altered consciousness [7,9], it may also have a negative effect on the survival of these patients.

For TCA patients, rapid intervention for potentially reversible injuries, such as thoracostomy for tension pneumothorax, is essential [10,11]. However, such advanced interventions are not

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always available at the injury scene because they must be performed by physicians or specially trained emergency medical service (EMS) personnel. In addition, in some countries, such as Japan, EMS personnel are legally prohibited from performing such interventions. In situations where prompt intervention is unavailable, rapid transportation to a hospital with basic life support (BLS), such as rescue breathing and chest compression, should be performed. Spinal immobilization may induce a time delay and difficulties associated with performing BLS, thereby resulting in further deterioration of a patient's condition.

In this study, we aimed to investigate the temporal trend of performing spinal immobilization on TCA patients and to examine the association between spinal immobilization and survival at discharge in patients with on-scene cardiac arrest caused by blunt trauma.

Methods

Setting

This is a retrospective cohort study using data from The Japan Trauma Data Bank (JTDB), 2004–2015. The JTDB is a nationwide trauma registry started in 2004 by the Japanese Association of Trauma Surgery and the Japanese Association for Acute Medicine [12]. As one of the largest trauma registries around the world [13], 254 emergency hospitals had enrolled in this registry by 2015, and over 90% of the data were collected from emergency and critical care centres (tertiary-level emergency hospitals), which are equivalent in role to level 1 trauma centres in the US and other countries [14]. Approximately 71% of these tertiary-level emergency hospitals in Japan were involved in the JTDB [14]. These hospitals collected patient data using web systems after anonymization. The present study was fully approved by the ethics committee of Kyoto University School of Medicine (reference number: R0208-2).

EMS care in Japan [15]

EMS personnel can perform standard BLS manoeuvres. In the case of cardiac arrest patients in Japan, trained ambulance personnel, known as emergency life-saving technicians (ELSTs), perform intravenous fluid administration, create adjunct airways such as via the insertion of a supraglottic airway device, and carry out defibrillation using semi-automated external defibrillators. Usually, ambulance crews include at least one ELST. ELSTs with special training have been authorized to perform tracheal intubation for cardiac arrest patients under the direct command of a physician since 2004. However, the performance by ELSTs of other advanced treatments for TCA patients, including needle or tube thoracostomy, emergency thoracotomy, and pericardiocentesis, are legally prohibited.

Patient selection and definitions

We included all adult blunt trauma patients who were already experiencing cardiac arrest when EMS personnel arrived at the injury scene. We defined cardiac arrest patients as those who underwent chest compression by emergency ambulance personnel without a palpable pulse at ambulance arrival. We excluded paediatric patients aged $<$16 years, patients who were not directly transferred from the scene, and patients who were treated by a physician at the scene. In addition, we excluded cases in which the time from the emergency call to EMS arrival at the scene was over 30 min and patients with a score of 6 points on the Abbreviated Injury Scale (AIS) for any body part, as these patients were likely to have no possibility of survival.

Primary exposure

The primary exposure was spinal immobilization using a backboard and/or cervical collar at the scene. We defined patients who underwent spinal immobilization as "immobilized patients" and those who did not as "non-immobilized patients".

Primary and secondary outcomes

The primary outcome of interest was survival at discharge, and the secondary outcome was the return of spontaneous circulation (ROSC) by admission.

Covariates

We regarded baseline characteristics, including age, gender, and co-performed prehospital treatments by EMS personnel (e.g. use of a supraglottic airway device, defibrillator, and intravenous fluid) as potential confounders, along with the year of the event. We hypothesized that the number of survivors in each year would be small; therefore, we categorized the year of the event into four phases: 2004 to 2006, 2007 to 2009, 2010 to 2012, and 2013 to 2015. In addition, we regarded the time from the emergency call to EMS arrival at the scene as a potential prognostic factor, since a delay in the initiation of treatment can affect the probability of survival. Finally, we regarded the Injury Severity Score (ISS) and presence or absence of an AIS $>$ 3 at the head, chest, abdomen, or pelvis as confounders. All potential confounders were included in the multivariable logistic regression model as covariates to estimate the association between spinal immobilization and the primary and secondary outcomes.

Statistical analyses

We described the patients' characteristics by comparing patient demographic factors between the immobilization and non-immobilization groups. Continuous variables are presented as the mean (standard deviation) or median (interquartile range), as appropriate. Categorical variables are shown as numbers (%). We used Student's *t*-test or Wilcoxon's rank sum test for continuous variables and Pearson's chi-squared test for categorical variables when performing between-group comparisons. We also described the time trend of immobilization using proportions and survival proportions. We used a Wilcoxon-type test for trends [16].

We examined the association between spinal immobilization and the probability of survival at discharge and the probability of ROSC by admission using a multivariable logistic regression model. We handled missing data by performing our primary analysis based on an imputed dataset using the multiple imputation method [17]. We imputed any missing data from the outcomes and covariates using our measured data. We generated 20 imputed datasets and combined the estimated values of the coefficients across these datasets. We included clinically important covariates in the model. As a sensitivity analysis, we also conducted a complete case analysis and sub-group analysis among patients with and without cervical spine injury. We accounted for hospital clustering using robust sandwich covariance estimators in all analyses. Additionally, to examine differences in the rate of survival among different mechanisms of injury, we performed an exploratory subgroup analysis using a univariate logistic regression model. To explore the difference of the association between spinal immobilization and outcome by each sub-group, we used a test of interaction between spinal immobilization and cervical spine injury or mechanism of injury.

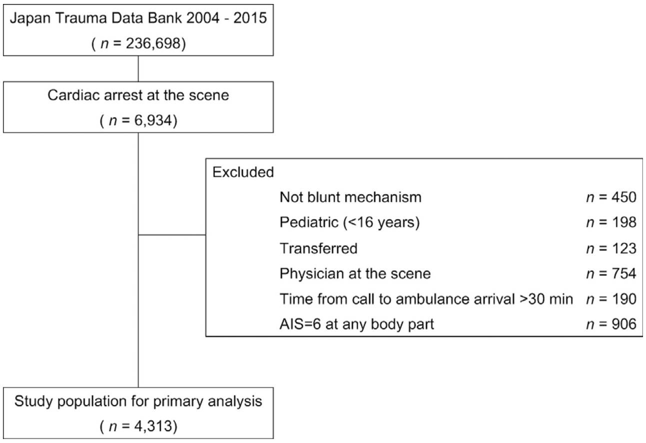

Fig. 1. Patient flow for the present study.

Results

Patient demographics

A total of 236,698 patients were registered in the JTDB 2004–2015. Among them, 4313 were eligible as adult on-scene blunt TCA patients (Fig. 1). The patient characteristics and outcomes are shown in Table 1. Among the 4313 patients, 3307 (76.7%) and 1006 (23.3%) were and were not immobilized, respectively. Immobilized patients had a higher median ISS and higher proportion of chest injury (AIS > 3) than non-immobilized patients. There was no significant difference in the time from ambulance arrival at the scene to hospital arrival between the immobilized and non-immobilized groups. In our study population, 1.0% of immobilized and 0.9% of non-immobilized patients had severe cervical spine injury (AIS > 3). The number of missing values for covariates was 45 (1.0%) for age, 828 (19.2%) for ISS, 149 (3.5%) for head injury, 36 (0.8%) for neck injury, 209 (4.8%) for chest injury, 62 (1.4%) for abdominal injury, and 15 (0.3%) for pelvic injury. A total of 181 patients (4.2%) had missing values for survival at discharge, and 213 (4.9%) had missing values for ROSC by admission. The usage rate of spinal immobilization decreased from 82.7% in 2004–2006 to 74.0% in 2013–2015 (p for trend <0.001), and the crude survival proportion at discharge increased from 1.2% in 2004–2006 to 2.8% in 2013–2015 during the study period (p for trend = 0.02) (Figs. 2 and 3).

Association between spinal immobilization and outcomes

For the primary outcome, 57 patients (1.8%) in the immobilized group and 36 (3.7%) in the non-immobilized group survived to

Table 1
Unadjusted comparison of immobilized vs. non-immobilized patients.

	Immobilized n = 3307	Non-immobilized n = 1006	p value
Age, mean (SD)	50.6 (20.1)	53.4 (20.7)	<0.001
missing, numbers	33	12	
Male, number (%)	2228 (67.4)	665 (66.1)	0.45
Time from the emergency call to EMS arrival at scene, minutes median (IQR)	7 (5–9)	7 (5–9)	0.25
Time from EMS arrival at scene to hospital arrival, minutes median (IQR)	23 (18–30)	22.5 (17–29)	0.48
Cause of injury, number (%)			<0.001
Motor vehicle crash	428 (12.9)	148 (14.7)	
Motor cycle crash	414 (12.5)	81 (8.1)	
Bicycle crash	204 (6.2)	54 (5.4)	
Pedestrian crash	488 (14.8)	109 (10.8)	
Fall from height	1410 (42.6)	364 (36.2)	
Others	363 (11)	250 (24.9)	
Prehospital care, number (%)			0.83
Airway	360 (10.9)	99 (9.8)	0.35
Defibrillation	91 (2.8)	27 (2.7)	0.91
Intravenous fluid	561 (17.0)	161 (16.0)	0.48
Backboard and cervical collar	2278 (68.9)[a]	0	N.A.
Backboard only	755 (22.8)[a]	0	N.A.
Cervical collar only	274 (8.3)[a]	0	N.A.
Year of injury, number (%)			<0.001
2004–2006	343 (10.4)	72 (7.2)	
2007–2009	711 (21.5)	177 (17.6)	
2010–2012	1215 (36.7)	393 (39.1)	
2013–2015	1038 (31.4)	364 (36.2)	
ISS, median (IQR)	29 (22–41)	23 (18–30)	<0.001
missing, number	587	241	
Neck injury, number (%)	302 (9.1)	85 (8.4)	0.51
Neck injury (AIS > 3), number (%)	34 (1.0)	9 (0.9)	0.71
missing, number	30	6	
Head injury (AIS > 3), number (%)	666 (20.1)	205 (20.4)	0.87
missing, number	126	23	
Chest injury (AIS > 3), number (%)	1723 (52.1)	392 (39.0)	<0.001
missing, number	168	41	
Abdominal injury (AIS > 3), number (%)	86 (2.6)	18 (1.8)	0.14
missing, number	47	15	
Pelvic injury (AIS > 3), number (%)	526 (15.9)	133 (13.2)	0.04
missing, number	13	2	
Survival at discharge, number (%)	57 (1.8)	36 (3.7)	<0.001
missing, number	74	29	
ROSC by admission, number (%)	788 (25.0)	395 (41.9)	<0.001
missing, number	149	64	

EMS, Emergency Medical Service; ISS, Injury Severity Score; AIS, Abbreviated Injury Scale; ROSC, Return of Spontaneous Circulation.
[a] Percentage calculated for immobilized patients.

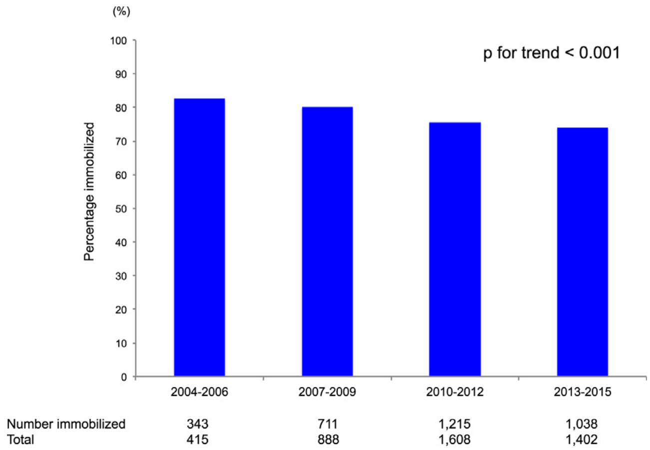

Fig. 2. Usage rate of spinal immobilization decreased over the study period.

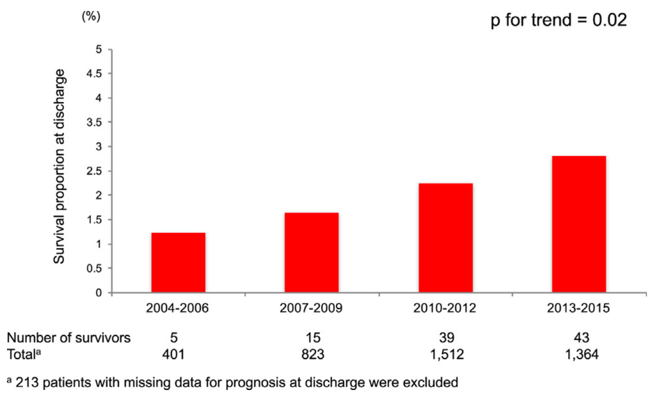

Fig. 3. Crude survival proportion at discharge increased over the study period.

discharge (Table 1). A multivariable analysis using a logistic regression model based on imputed data showed that the immobilized group had a lower possibility of survival to discharge than the non-immobilized group (odds ratio [OR], 0.64; 95% confidence interval [CI], 0.42 to 0.98).

For the analysis of the secondary outcome, 788 patients (25.0%) in the immobilized group and 395 (41.9%) in the non-immobilized group achieved ROSC by admission. A multivariable analysis after multiple imputations also showed that the immobilized group had a lower proportion of ROSC by admission than the non-immobilized group (OR, 0.48; 95% CI, 0.27 to 0.87).

The results of a sub-group analysis among patients with or without cervical spine injury showed no significant sub-group difference of the association between spinal immobilization and survival (p for interaction 0.73) (Table 2). However, there was a significant sub-group difference of the association between spinal immobilization and ROSC by patients with or without cervical spine injury (p for interaction <0.01) (Table 2).

As a sensitivity analysis, we performed a complete case analysis. The results were consistent with those obtained in our primary analysis (Appendix Table Appendix in Supplementary material). Exploratory subgroup analysis based on mechanisms of injury using a univariate logistic regression model showed no significant sub-group difference of the association between immobilization and survival (p for interaction 0.38) (Figure Appendix in Supplementary material).

Discussion

In this study, we found that 76.7% of blunt TCA patients underwent spinal immobilization, which was significantly associated with a lower rate of survival at discharge and ROSC by admission. Given these results, we suggest that spinal immobilization should not be routinely recommended for blunt TCA patients.

Several drawbacks have been reported for spinal immobilization, such as increased intracranial pressure [18,19] and compromised airway and respiratory function [20,21]. For TCA patients, increased intracranial pressure may worsen severe head injury. In addition, a cervical collar and head immobilizer may compromise airway management, and straps may tighten the chest, which can hamper rescue breathing efforts. These reasons may explain why spinal immobilization was significantly associated with a lower rate of survival and ROSC among blunt TCA patients in our study. Although delayed transfer has been regarded as a potential disadvantage of spinal immobilization [8,20], we noted no significant difference in the median duration from EMS arrival at the scene to hospital arrival between the immobilization groups; this may be due, at least in part, to the fact that approximately 30% of immobilized patients in our study received either a cervical collar or backboard immobilization, but not both. Taken together, these findings suggest that the disadvantages inherent to spinal immobilization itself can negatively affect the survival rate of blunt TCA patients, even without a marked delay in the time between EMS arrival at the scene and patient admission to a hospital. In addition, while not a significant factor, we cannot ignore the possibility that attachment time might have interrupted cardiopulmonary resuscitation, since only 10 s of interruption of a chest compression is sufficient to increase mortality in cardiac arrest patients [22]. Our results are consistent with a recent Norwegian guideline, which recommends that spinal immobilization should not worsen the condition for severely injured patients [23].

Table 2
Difference of survival at discharge and ROSC to admission between Immobilized and Non-immobilized patients.

	All patients (n = 4313)		Without cervical spine injury (n = 3895)		With cervical spine injury (n = 382)		
	OR	95% CI	OR	95% CI	OR	95% CI	p for interaction
Survival at discharge							0.73
Immobilized	0.64	0.42 to 0.98	0.56	0.34 to 0.92	0.90	0.34 to 2.39	
Non-immobilized	Ref.		Ref.		Ref.		
ROSC to admission							<0.01
Immobilized	0.48	0.27 to 0.87	0.41	0.22 to 0.78	1.33	0.79 to 2.23	
Non-immobilized	Ref.		Ref.		Ref.		

ROSC, Return of Spontaneous Circulation; OR, Odds Ratio; CI, Confidence Interval.
Adjusted for age, gender, gender, co-performed prehospital treatments by EMS personnel (supraglottic airway device, defibrillator and intravenous fluid), time from the emergency call to EMS arrival at the scene, year of the event (four categories), Injury Severity Score (ISS), and the presence or absence of injury AIS > 3 at the head, chest, abdomen and pelvis.

We also found that the proportion of patients who underwent spinal immobilization decreased over the 12-year study period in Japan. However, over 70% of blunt TCA patients were still receiving spinal immobilization in the 2013–2015 period. Although spinal immobilization may be beneficial for patients with severe cervical spine injury, several previous studies have shown that this injury comprised only approximately 2% of all blunt trauma patients [20,24,25]. Our results were consistent with those of previous studies showing that less than 10% of patients had any sort of cervical spine injury and that only about 1% of patients had serious injury, although TCA patients may be at greater risk of cervical spine injury than the general blunt trauma population. Therefore, EMS personnel should more carefully consider the implications of spinal immobilization for blunt TCA patients. In addition, according to the results of sub-group analysis, spinal immobilization may be more harmful on ROSC among patients without cervical spine injury than those who with. However, as the number of patients with cervical spine injury was small in the present study, we cannot draw any hard conclusions concerning whether immobilization was harmful or beneficial for blunt TCA patients with cervical spine injury. Additionally, our exploratory subgroup analysis showed no significant difference of the association between spinal immobilization and survival by different mechanisms of injury. It should be noted, however, that this exploratory analysis comprised only a small number of patients for each mechanism. Therefore, further study is needed to examine the association between mechanisms of injury and the effects of spinal immobilization in blunt traumatic cardiac arrest.

Several strengths to the present study warrant mention. First, to our knowledge, this is the first study to examine the effects of spinal immobilization in blunt TCA patients. Second, our results were based on cohort data obtained in a large-scale nation-wide study and included both pre-hospital and in-hospital information. Finally, we used the multiple imputation method to account for missing data and confirmed the robustness of our results by conducting a complete-case analysis as a sensitivity analysis.

Several limitations to our study also warrant mention. First, our cohort lacked information regarding neurological outcomes, which is as clinically important as survival. Further studies investigating the association between spinal immobilization and neurological outcomes are needed. Second, our study was based on data concerning the Japanese emergency care system. Therefore, our results may not be comparable to those from other countries. In addition, we were unable to reveal the causality between spinal immobilization and survival or ROSC due to the retrospective observational design of this study. Moreover, because of the observational design, we cannot exclude the effect of residual confounding factors, such as unmeasured severe limitations of CPR. Therefore, our results should be interpreted with caution, and further studies are needed to confirm our results.

Conclusion

Spinal immobilization is widely used even for blunt TCA patients, even though it is associated with a lower rate of survival at discharge and ROSC by admission. We suggest that spinal immobilization should not be routinely recommended for all blunt TCA patients. EMS personnel should more carefully consider the implications of spinal immobilization for blunt TCA patients. Further studies investigating the association between spinal immobilization and neurological outcomes are needed.

Conflict of interest statement

None.

Acknowledgements

We would like to thank all members and personnel of the JTDB, the Japanese Association for Trauma Surgery, the Japanese Association for Acute Medicine, and Japan Trauma Care and Research.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.injury.2017.09.005.

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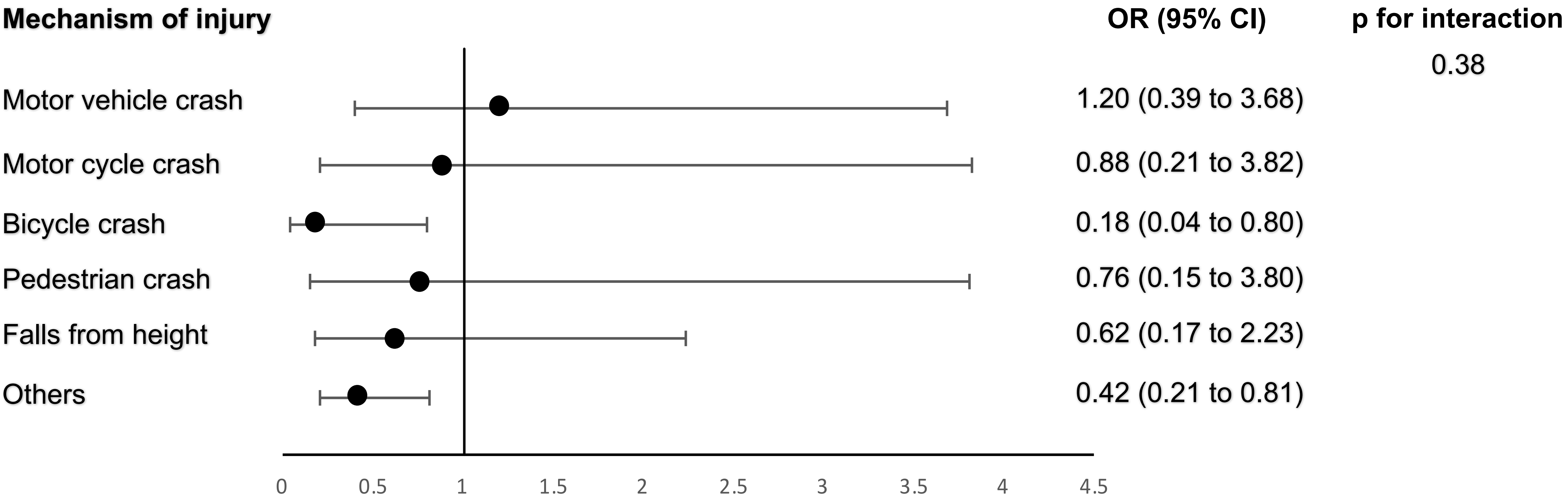
Appendix Table 1. Difference in survival at discharge and ROSC by admission between immobilized and non-immobilized patients (complete case analysis)

	All patients		Without cervical spine injury		With cervical spine injury		
	OR	95% CI	OR	95% CI	OR	95% CI	p for interaction
Survival at discharge							0.72
Immobilized	0.63	0.40 to 0.98	0.57	0.33 to 0.96	0.90	0.35 to 2.34	
Non-immobilized	Ref.		Ref.		Ref.		
ROSC to admission							0.01
Immobilized	0.52	0.28 to 0.94	0.46	0.24 to 0.87	1.27	0.75 to 2.15	
Non-immobilized	Ref.		Ref.		Ref.		

ROSC, Return of Spontaneous Circulation; OR, Odds Ratio; CI, Confidence Interval

Adjusted for age, gender, gender, co-performed prehospital treatments by EMS personnel (supraglottic airway device, defibrillator and intravenous fluid), time from the emergency call to EMS arrival at the scene, year of the event (four categories), Injury Severity Score (ISS), and the presence or absence of injury AIS > 3 at the head, chest, abdomen and pelvis.

Figure Appendix



OR, Odds Ratio; CI, Confidence Interval

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Corrigendum

Corrigendum to ‘Association between spinal immobilization and survival at discharge for on-scene blunt traumatic cardiac arrest: A nationwide retrospective cohort study’ [Injury 49 (1) (2017) 124–129]

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The authors regret that the main text, Table 1, and Figure 2 contain some incorrect information. In the manuscript, we described thenumber of missing of “Survival at discharge”was 181 (4.2%),this is incorrect. The correct number is103 (2.4%), as can be calculated by the data given in Table 1. In Table 1, there is a meaningless p-value of 0.83 in the row titled “Prehospital care”. Furthermore, there are incorrect values of ISS for non-immobilized patients, an incorrect p-value for Head injury (AIS>3), and an incorrect number of patients who had neck injury in the Immobilized group, this was caused by mistakes in copying original data to the table. Additionally, the proportions of AIS >3 for each body part were wrong because we mistakenly calculated the proportions without accounting for missing values. In Figure 3, the bar chart is correct, but the number of survivors and total patients is incorrect. We mistakenly described the number of patients who had no missing values for “ROSC by admission” rather than the number of patients who had no missing values for “Survival at discharge”. The correct Table 1 and Figure 3 are given below. These errors do not change the scientific conclusions of the study in any way. The authors would like to apologise for any inconvenience caused.

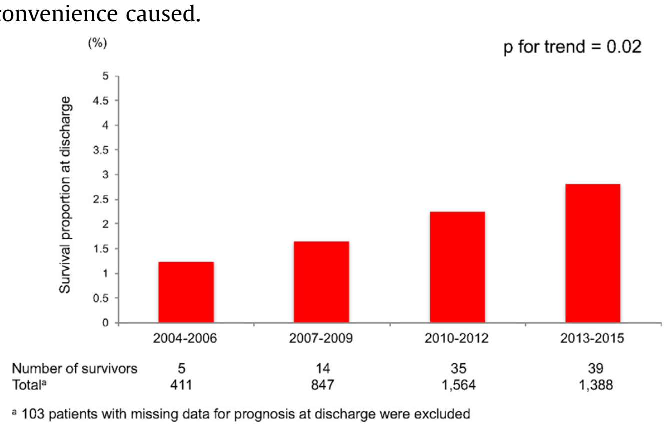

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Table 1
Unadjusted comparison of immobilized vs. non-immobilized patients.

	Immobilized	Non-immobilized	
	n = 3,307	n = 1,006	p value
Age, mean (SD)	50.6 (20.1)	53.4 (20.7)	<0.001
missing, numbers	33	12	
Male, number (%)	2228 (67.4)	665 (66.1)	0.45
Time from the emergency call to EMS arrival at scene, minutes median (IQR)	7 (5 to 9)	7 (5 to 9)	0.25
Time from EMS arrival at scene to hospital arrival, minutes median (IQR)	23 (18 to 30)	22.5 (17 to 29)	0.48
Cause of injury, number (%)			<0.001
Motor vehicle crash	428 (12.9)	148 (14.7)	
Motor cycle crash	414 (12.5)	81 (8.1)	
Bicycle crash	204 (6.2)	54 (5.4)	
Pedestrian crash	488 (14.8)	109 (10.8)	
Fall from height	1,410 (42.6)	364 (36.2)	
Others	363 (11.0)	250 (24.9)	
Prehospital care, number (%)			
Airway	360 (10.9)	99 (9.8)	0.35
Defibrillation	91 (2.8)	27 (2.7)	0.91
Intravenous fluid	561 (17.0)	161 (16.0)	0.48
Backboard and cervical collar	2,278 (68.9)[a]	0	N.A.
Backboard only	755 (22.8)[a]	0	N.A.
Cervical collar only	274 (8.3)[a]	0	N.A.
Year of injury, number (%)			<0.001
2004-2006	343 (10.4)	72 (7.2)	
2007-2009	711 (21.5)	177 (17.6)	
2010-2012	1,215 (36.7)	393 (39.1)	
2013-2015	1,038 (31.4)	364 (36.2)	
ISS, median (IQR)	29 (22 to 41)	25 (18 to 38)	<0.001
missing, number	587	241	
Neck injury, number (%)	297 (9.1)	85 (8.5)	0.58
Neck injury (AIS > 3), number (%)	33 (1.0)	9 (0.9)	0.76
missing, number	30	6	
Head injury (AIS > 3), number (%)	666 (20.9)	205 (20.9)	0.96
missing, number	126	23	
Chest injury (AIS > 3), number (%)	1,723 (54.9)	392 (40.6)	<0.001
missing, number	168	41	
Abdominal injury (AIS > 3), number (%)	86 (2.6)	18 (1.8)	0.14
missing, number	47	15	
Pelvic injury (AIS > 3), number (%)	526 (16.0)	133 (13.2)	0.04
missing, number	13	2	
Survival at discharge, number (%)	57 (1.8)	36 (3.7)	<0.001
missing, number	74	29	
ROSC by admission, number (%)	788 (25.0)	395 (41.9)	<0.001
missing, number	149	64	

EMS, Emergency Medical Service; ISS, Injury Severity Score; AIS, Abbreviated Injury Scale; ROSC, Return of Spontaneous Circulation.
[a] Percentage calculated for immobilized patients.

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