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Association of prehospital optimal blood pressure and peripheral oxygen saturation with hospital outcomes in sports-related and recreation-related traumatic brain injury (SRR-TBI) in Asia

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ABSTRACT

Background While Emergency Medical Services (EMS) guidelines improve outcomes in severe traumatic brain injury (TBI), the effect of optimal blood pressure and oxygenation on sports-related and recreation-related TBI (SRR-TBI) is unclear. This study assessed whether EMS management of systolic blood pressure (SBP) and oxygen saturation (SpO_2) influences outcomes in SRR-TBI.

Methods This retrospective cohort study analysed data from patients diagnosed with TBI sustaining injuries during sports, education or leisure activities and were transported by EMS from 1 January 2016 to 31 December 2022, at Pan-Asian Trauma Outcomes Study facilities. Patients were classified as receiving *optimal care* (SBP>110 mm Hg and SpO_2>94%), *intermediate care* (either SBP<110 mm Hg or SpO_2<94%) or *suboptimal care* (both <thresholds). Outcomes were favourable neurological recovery (Modified Rankin Scale 0–3) and survival to discharge. Adjusted ORs with 95% CIs were calculated using multivariable logistic regression, adjusting for activity, age, sex, Charlson Comorbidity Index, mechanism and intent of injury, alcohol intake, time of injury and the Excess Mortality Ratio-adjusted Injury Severity Score.

Results Among 4629 patients, 74% were male and 18.4% were <18 years old. Injuries occurred during education (3%), sports (14.5%) and leisure (82.5%). Care was optimal in 77.7%, intermediate in 19.6% and suboptimal in 2.7%. Favourable outcomes were 96.3%, 88.7% and 76%, with mortality of 0.9%, 4.7% and 8.8%, respectively (p<0.0001). Compared with suboptimal care, adjusted odds of favourable recovery and survival were 2.76 and 3.30 for optimal care, and 1.27 and 1.01 for intermediate care.

Conclusion Maintaining optimal SBP and SpO_2 during EMS care is associated with better neurological outcomes and survival in patients with SRR-TBI.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Compliance with Emergency Medical Services (EMS) guidelines for traumatic brain injury (TBI) is well established in improving outcomes for patients with severe TBI.

⇒ However, there is limited evidence regarding whether these guidelines are associated with better outcomes in patients with sports-related and recreation-related TBI (SRR-TBI).

WHAT THIS STUDY ADDS

⇒ This retrospective cohort study analysed data from adults diagnosed with TBI who sustained injuries during sports, education or leisure activities and were transported by EMS from 1 January 2016 to 31 December 2022, to Pan-Asian Trauma Outcomes Study hospitals.

⇒ Appropriate EMS treatment aimed at correcting suboptimal blood pressure and oxygen saturation (SpO_2) was associated with improved outcomes in patients with SRR-TBI across all levels of injury severity.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Our findings suggest that maintaining a systolic blood pressure of ≥140 mm Hg and peripheral SpO_2 of ≥94% during EMS care is associated with improved neurological outcomes and survival in patients with SRR-TBI, and therefore merits reconsideration of prehospital TBI management thresholds.

BACKGROUND

Traumatic brain injury (TBI) is a major global health burden, affecting an estimated 50 million people annually and contributing to the loss of 8 million years of healthy life due to disability.[1 2] Road traffic accidents (RTAs) and falls are the leading causes worldwide, but sports and recreational activities are the predominant cause of TBI in children and adolescents.[3 4] Sports-related and recreation-related TBIs (SRR-TBI) account for about 10% of all TBIs and over 21% of TBIs in youth in the USA. Incidence ranges from 3.5 to 31.5 per 100 000, with severe cases comprising 2.8%–7.7% and average mortality of 3%.[5 6] Although most SRR-TBIs are mild to moderate, repetitive injuries can lead to long-term neuropsychiatric effects, including chronic traumatic encephalopathy, seen in at least 17% of patients.[7]

A high-performance Emergency Medical Services (EMS) system delivers care consistent with evidence-based guidelines. Prehospital TBI

guidelines, such as those from the Brain Trauma Foundation, recommend maintaining systolic blood pressure (SBP) above 90 mm Hg and oxygen saturation (SpO_2) above 90%, and have been linked to improved survival in severe TBI.[8] While the benefits of EMS protocols to maintain optimal blood pressure and SpO_2 in trauma patients and patients with TBI are well documented, most studies have focused on moderate to severe injuries resulting from RTAs or falls. Limited direct evidence exists regarding the association between EMS management and outcomes in patients with SRR-TBI.

This study investigates the association between EMS management of blood pressure and SpO_2 and hospital outcomes in patients with SRR-TBI.

METHODS

Study design

This is a registry-based observational study using the Pan-Asian Trauma Outcome Study (PATOS) database. The manuscript adheres to the Strengthening the Reporting of Observational Studies in Epidemiology reporting guidelines.

Data source

We used patient data from the PATOS, an international, multicentre registry aimed at describing injury epidemiology, comparing emergency care systems, benchmarking trauma care and improving patient outcomes across Asia-Pacific countries. PATOS includes data from 32 hospitals in China, India, Japan, South Korea, Malaysia, Singapore, Taiwan, Thailand, the United Arab Emirates and Vietnam, covering injury epidemiology, community risk factors, EMS interventions, ED management, and hospital treatments and discharge outcomes.

The PATOS registry commenced data collection on 1 January 2016, and has continuously recorded information at participating sites. A clinical research network of EMS directors, emergency physicians, trauma surgeons and epidemiologists oversees data quality and trains researchers. Data are primarily recorded by prehospital care providers, including emergency medical technicians, paramedics and EMS physicians, followed by hospital researchers, such as research assistants, nurses and physicians, who complete the registration using the PATOS data registry forms. Data are primarily entered by prehospital providers (Emergency Medical Technicians (EMTs), paramedics, EMS physicians) and hospital staff (research assistants, nurses, physicians) using PATOS registry forms. The Data Quality Management Committee ensures data set integrity, and all data are securely stored in an internet-based Electronic Data Capture (EDC) system hosted by the Study Coordinating Centre at Seoul National University Hospital, Korea.[9]

Study setting

Sports and recreational participation is widespread in Asia. An Association of Southeast Asian Nations (ASEAN) survey reported that 65% of the population engages in sports, mostly in dedicated facilities.[10] In South Korea, participation rose from 62.2% in 2018 to 66.6% in 2019, while a 2022 survey in Taiwan found 81.8% of the population exercises, with 34% exercising regularly.[10 11]

EMS systems in the PATOS network vary by country. China, Malaysia, the Philippines, Thailand and Vietnam use hospital-based EMS, whereas Japan, South Korea, Singapore and Taiwan use fire-based systems. Most operate single-tier systems with Basic Life Support (BLS) and Advanced Life Support (ALS) vehicles; ALS units typically include three personnel, often EMTs plus a nurse or paramedic.[12–14]

Most PATOS hospitals are urban, with 26% designated trauma centres and half having trauma care teams. Trauma care is provided by emergency physicians and trauma surgeons in approximately 60% of hospitals, and 10 countries issue specific certifications for trauma surgeons.[12–14]

Although most EMS systems follow international trauma guidelines, specific protocols for TBI or SRR-TBI are generally lacking. Existing protocols focus on general trauma, while ambulance services for mass sports events are organised by national or local authorities.

Study population

Data on patients with SRR-TBI presenting to PATOS facilities between 1 January 2016 and 31 December 2022, were extracted from the PATOS database. TBI was identified using the International Statistical Classification of Diseases and Related Health Problems, 10th Revision, Clinical Modification (ICD-10-CM) codes S00–S09 from discharge diagnoses. Sports and recreational activities, defined according to the International Classification of External Causes of Injury, included playing, practice, training and competition. Activities were classified by location and purpose as educational (school events or gym classes), sports (practice or events at sports facilities) or leisure (public gyms, roads or other settings). Activity data were obtained from medical history or EMS records and recorded in the database by prehospital providers, nurses or physicians.

Patients were excluded if activity was unknown, prehospital blood pressure or SpO_2 was missing, outcome data were incomplete, or if data collection at a study site ceased within 6 months of registry participation due to quality concerns.

Data collection procedures

Data were reviewed and recorded by site research coordinators using medical records. Unclear outcomes were resolved in consultation with the site principal investigator (PI). Coordinators and PIs were blinded to the study hypothesis, and data abstractors were unaware of the study's objectives. The data set and inclusion criteria were predetermined by the study authors before data request to minimise bias.

Study variables

The primary exposure variable was EMS treatment. Optimal care for TBI was defined as continuous monitoring and maintaining a SBP $\geq$110 mm Hg and $SpO_2 \geq 94\%$, which is in line with current EMS guidelines.[8 15]

Patients were considered to have received optimal care if: (1) SBP <110 mm Hg was documented and intravenous (IV) or intraosseous fluids were administered, or (2) SpO_2 <94% was documented and oxygen therapy, bag-valve-mask ventilation or advanced airway management was provided. Patients were classified as receiving optimal care if interventions were performed, regardless of success at hospital arrival. Lack of intervention for abnormal values was classified as suboptimal care.

Patients were categorised into three groups: Group 1 (Optimal Care)—optimal care for both SBP and SpO_2, or normal values without unnecessary interventions; Group 2 (Intermediate Care)—optimal care for one parameter but suboptimal care for the other; Group 3 (Suboptimal Care)—suboptimal care for both.

Potential confounders included demographics, injury epidemiology (mechanism, intent, alcohol use, activity type) and injury

severity. Severity was measured using the Excess Mortality Ratio-adjusted Injury Severity Score (EMR-ISS), derived from ICD-10-CM, ranging 1–74 and categorised as mild (1–9), moderate (10–24) and severe (≥25).[16]

Study outcomes

The primary outcome was disability at hospital discharge, measured by the Modified Rankin Scale (MRS). Outcomes were categorised as favourable (MRS 0–3: no, slight or moderate disability) or poor (MRS 4–6: moderately severe disability, severe disability or death). The secondary outcome was survival at discharge.

Statistical analysis

Categorical variables were compared as counts and percentages using χ^2 tests and the continuous variables were compared as medians and IQRs. We used the Shapiro-Wilk test to assess the normality of our continuous variables and found that the data did not follow a normal distribution. Therefore, we employed the Wilcoxon rank-sum test for comparisons of continuous variables, as it is a non-parametrical alternative suitable for non-normally distributed data. A value of $p<0.05$ was considered statistically significant. We categorised the continuous variables age and EMR-ISS based on established clinical cut-offs commonly used in trauma research: age was grouped as children (0–17 years), adults (18–59 years) and elderly (≥60 years), while EMR-ISS was categorised according to validated scoring criteria. Categories were further refined using the distribution of our data set to enhance interpretability and model stability.

Multivariable logistic regression was used to determine the association between optimal performance by EMS and functional outcome at discharge (the reference group=low EMS performance group) with adjustment for confounders. The discrimination of the regression model was tested using the area under the receiver operating characteristic curve (AUROC) and calibration performance was tested using the Hosmer-Lemeshow test. Adjusted OR (AORs) with 95% CIs of optimal groups compared with suboptimal groups on study outcomes were calculated from this multivariable logistic regression.

MISSING DATA

A monotone logistic regression imputation was used to address missing data to ensure that the analysis included as many cases as possible while maintaining data integrity. The imputation model included patient demographics, injury severities and injury mechanisms as predictors to account for relationships among variables. Critical variables such as primary outcomes and intervention were not imputed. Cases with missing values for these variables were excluded from the analysis to preserve the reliability and robustness of the results.

Patient and public involvement

No patient was involved.

RESULTS

Demographics

Of 66 625 patients with TBI, 4629 were eligible for analysis. Exclusions included 58 794 patients injured outside education, sports or leisure activities; 2193 transported by non-ambulance means; 901 with missing SBP or SpO_2; and 108 with unknown MRS (figure 1).

Table 1 displays the characteristics and outcomes of patients according to the type of activity. Of the total patients, 3427 (74%) were male, 853 (18.4%) were under 18 years old and 137 (3%), 673 (14.5%) and 3819 (82.5%) were involved in education, sports and leisure activities, respectively. Optimal and suboptimal treatment was found in 3595 (77.7%) and 125 (2.7%) patients, respectively. The proportion of favourable functional outcomes was 97% in the education and sports group and 93.7% in the leisure group ($p<0.0001$). Mortality rates were 0.9% in the education and sports group and 2.1% in the leisure group ($p<0.02$).

Among the 4629 patients, 3595 (77.7%) received optimal care, 909 (19.6%) received intermediate care and 125 (2.7%) received suboptimal care (table 2). Suboptimal care was due to unnecessary oxygen therapy in 81 (64.8%) and/or no IV interventions in 79 (63.2%) patients. There was no significant difference in care given according to sex or activity, but there was a slightly lower percentage of optimal care in patients aged <18 years and traffic accidents. The proportion of favourable functional outcomes was 96.3%, 88.7% and 76% for the optimal, intermediate and suboptimal care groups, respectively ($p<0.0001$). Mortality rates were 0.9%, 4.7% and 8.8% in the optimal, intermediate and suboptimal care groups, respectively ($p<0.0001$).

Main results

The main results from the multivariable logistic regression analysis are presented in table 3. The AORs for favourable

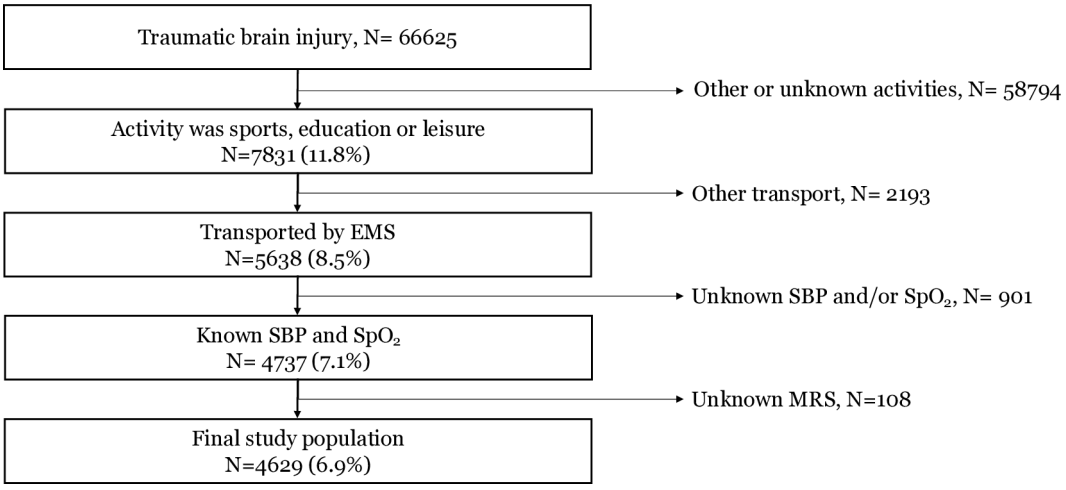

Figure 1 Study population. EMS, Emergency Medical Services; SBP, systolic blood pressure; SpO_2, oxygen saturation; MRS, Modified Rankin Scale.

Table 1 Study participants according to types of activities

Variable	All		Education		Sports		Leisure	
	4629	%	137	%	673	%	3819	%
Treatment								
Suboptimal	125	2.7	4	2.9	6	0.9	115	3
Intermediate	909	19.6	28	20.4	86	12.8	795	20.8
Optimal	3595	77.7	105	76.6	581	86.3	2909	76.2
Sex								
Male	3427	74	101	73.7	501	74.4	2825	74
Female	1202	26	36	26.3	172	25.6	994	26
Age group, years								
0–17	853	18.4	107	78.1	107	15.9	639	16.7
18–39	1389	30	27	19.7	203	30.2	1159	30.3
40–59	1256	27.1	1	0.7	205	30.5	1050	27.5
60–120	1131	24.4	2	1.5	158	23.5	971	25.4
Injury mechanism								
Traffic accident	1392	30.1	23	16.8	123	18.3	1246	32.6
Fall or slip down	2066	44.6	51	37.2	234	34.8	1781	46.6
Collision and others	1172	25.3	63	46	316	47	792	20.7
Injury intent								
Accidental	4330	93.5	132	96.4	665	98.8	3533	92.5
Intentional	299	6.5	5	3.6	8	1.2	286	7.5
Alcohol consumption								
Yes	2742	59.2	6	4.4	32	4.8	1970	51.6
No	1887	40.8	131	95.6	641	95.2	1849	48.4
CCI								
0	4208	90.9	137	100	629	93.5	3442	90.1
>1	421	9.1	0	0	44	6.5	377	9.9
EMR-ISS								
1~14	3266	70.6	118	86.1	522	77.6	2626	68.8
15–23	515	11.1	10	7.3	77	11.4	428	11.2
24–75	848	18.3	9	6.6	74	11	765	20
Outcomes								
MRS								
Favourable functional outcomes (0–3)	4363	94.3	135	98.5	651	96.7	3577	93.7
Poor functional outcomes (4-6)	266	5.7	2	1.5	22	3.3	242	6.3
Death	87	7	2	1.5	5	0.7	80	2.1

CCI, Charlson Comorbidity Index; EMR-ISS, Excess Mortality Ratio-adjusted Injury Severity Score; MRS, Modified Rankin Scale.

neurological recovery and survival, compared with suboptimal care (reference group), were 2.76 (95% CI 1.67 to 4.58) and 3.30 (95% CI 1.54 to 7.07) for the optimal care group, and 1.27 (95% CI 0.73 to 2.06) and 1.01 (95% CI 0.48 to 2.13) for the intermediate care group, respectively. The AUROC and value of p and survival are available in online supplemental material.

DISCUSSION

This study demonstrates that maintaining optimal blood pressure and peripheral SpO_2 during prehospital care is significantly associated with better outcomes for patients with TBI related to sports and recreational activities compared with those who received intermediate or suboptimal care. Notably, patients who received intermediate care did not show significantly different outcomes compared with those who received suboptimal care. This highlights the importance of treating hypotension and hypoxia in patients with suspected SRR-TBIs.

Numerous studies have established the association between hypotension and hypoxia with increased mortality in patients with TBI, which forms the foundation of current prehospital TBI guidelines.[15 17] The Excellence in Prehospital Injury Care Trial (EPIC Trial), a large statewide study in the USA, found that implementing prehospital treatment protocols significantly improved survival to hospital admission among patients with severe TBI (AOR, 2.03; 95% CI 1.52 to 2.72; p<0.001).[8] This underlines the critical role of high-performance EMS in the care of patients with TBI. Although our study used different treatment parameters than the EPIC Trial (maintaining SBP>90 mm Hg and SpO_2>90% in the EPIC Trial vs SBP>110 mm Hg and SpO_2>94% in this study), we observed similar positive outcomes. Furthermore, our study found no significant difference in outcomes between the intermediate care and suboptimal care groups, which emphasises that both hypotension and hypoxia should be aggressively managed in patients with SRR-TBI.

In our cohort, 64.8% of patients in the suboptimal care group were subjected to unnecessary oxygen therapy. Additionally, a significant proportion of these patients (63.2%) did not receive IV interventions when necessary. One possible explanation for this suboptimal care is the under-recognition of TBI by prehospital personnel, which has been documented in previous studies.

Table 2 Study participants according to treatment given

Variable	All		Suboptimal		Intermediate		Optimal	
		%		%		%		%
All	4629	100	125	2.7	909	19.6	3595	77.7
Sex								
Male	3427	74	103	3	643	18.8	2681	78.2
Female	1202	26	22	1.8	266	22.1	914	76
Age group, years								
0–17	853	18.4	24	2.8	230	27	599	70.2
18–39	1389	30	35	2.5	257	18.5	1097	79
40–59	1256	27.1	38	3	200	15.9	1018	81.1
60–120	1131	24.4	28	2.5	222	19.6	881	77.9
Activity								
Education and sports	810	17.5	10	1.2	114	14.1	686	84.7
Leisure	3819	82.5	115	3	795	20.8	2909	76.2
Injury mechanism								
Traffic accident	1392	30.1	76	5.5	325	23.3	991	71.2
Fall or slip down	2066	44.6	39	1.9	398	19.3	1629	78.8
Collision and others	1171	25.3	10	0.9	186	15.9	975	83.3
Injury intent								
Accidental	4330	93.5	120	2.8	874	20.2	3336	77
Intentional	299	6.5	5	1.7	35	11.7	259	86.6
Alcohol consumption								
Yes	2742	59.2	64	2.3	512	18.7	2166	79
No	1887	40.8	61	3.2	397	21	1429	75.7
CCI								
0	4208	90.9	114	2.7	835	19.8	3259	77.4
>1	421	9.1	11	2.6	74	17.6	336	79.8
EMR-ISS								
1~14	3266	70.6	40	1.2	571	17.5	2655	81.3
15~23	515	11.1	12	2.3	88	17.1	415	80.6
24~75	848	18.3	73	8.6	250	29.5	525	61.9
Interventions								
IV therapy								
Yes	211	4.6	46	21.8	130	61.6	35	16.6
No	4418	95.4	79	1.8	779	17.6	3560	80.6
Oxygen therapy								
Yes	385	8.3	81	21	201	52.2	103	26.8
No	4244	91.7	44	1	708	16.7	3492	82.3
Outcomes								
MRS								
Favourable functional outcomes (0–3)	4363	94.3	95	2.2	806	18.5	3462	79.3
Poor functional outcomes (4-6)	266	5.7	30	11.3	103	38.7	133	50
Death	87	1.9	11	12.6	43	49.4	33	37.9

CCI, Charlson Comorbidity Index; EMR-ISS, Excess Mortality Ratio-adjusted Injury Severity Score; IV, Intravenous; MRS, Modified Rankin Scale.

For example, a study in the USA found that undertriage of patients with TBI often leads to missed diagnoses and delayed treatment.[18] In addition, the patterns we observed may be partly explained by the disuse or inconsistent application of existing guidelines by EMS personnel. This finding suggests a critical need for the implementation of standardised EMS TBI treatment protocols across Asian countries.

Data on ED visits and EMS use for SRR-TBI in Asia remain scarce. In the USA, it is estimated that 10% of all TBIs result from sports and recreational activities, with 3%–15% of these being classified as severe injuries.[19] Our study revealed similar findings, with 11.8% of patients with TBI presenting after participating in education, sports or leisure activities, and 18.3% of these cases being classified as severe injuries. A study from the USA reported that EMS activation for sports-related injuries was between 0.2% and 0.3%, with more than two-thirds of cases involving adults.[20] Additionally, only about 7% of paediatric patients with sports-related injuries were transported to the ED via ambulances, with TBI being the third most common cause of these injuries.[5 21] However, there have been no studies specifically investigating EMS treatment and outcomes for patients with SRR-TBI. One study comparing the use of helicopter versus ground transportation for skiers and snowboarders with TBIs found that prehospital helicopter transport improved survival outcomes compared with ground EMS.[22] In our study, 8.5% of patients with SRR-TBI were transported by EMS, and 18.4% were children (aged 0–17

Table 3 Multivariable logistic regression analysis for outcomes by treatment given

Exposure	Outcomes	Group	Total	Outcomes				
			N	n	%	AOR	95% CI	
Treatment								
	Favourable neurological recovery	Total	4629	4363	94.3			
		Suboptimal	125	95	76.0	1.00		
		Intermediate	909	806	88.7	1.27	0.73	2.06
		Optimal	3595	3462	96.3	2.76	1.67	4.58
	Survival	Total	4629	4542	98.1			
		Suboptimal	125	114	91.2	1.00		
		Intermediate	909	866	95.3	1.01	0.48	2.13
		Optimal	3595	3562	99.1	3.30	1.54	7.07

The multivariable logistic regression model for outcomes by treatment given was adjusted for activity, age, sex, Charlson Comorbidity Index, mechanism of injury, Injury intent, alcohol intake, time of injury and Excess Mortality Ratio-adjusted Injury Severity Score. The full multivariate models are available in the online supplemental material.
AOR, adjusted OR

years). However, we did not specifically examine whether the mode of transportation affected patient outcomes.

While our study did not capture detailed information on the specific types of activities involved in the injuries, approximately 30% of SRR-TBIs were associated with RTAs (10.5% in education and sports and 19.5% in leisure activities). This may reflect activities occurring on or near roadways, such as cycling, running or walking, which inherently carry a higher risk of collision with vehicles. This warrants further investigation to allow for the development of tailored prevention strategies. Additionally, there is a lack of studies in Asia examining the care costs associated with SRR-TBI or TBI in general. This gap in knowledge further emphasises the need for research on the economic burden of SRR-TBIs to inform public health policy and resource allocation.

Limitations

This study has several limitations. First, it is a retrospective analysis based on EMS run sheets completed by EMS personnel, duty physicians, surgeons and researchers. As such, there is potential for missing or inaccurate data. Additionally, patients with incomplete medical records or missing data on key variables or outcomes were excluded (1.5%), which may have minimally affected the generalisability of the findings.

Second, the data on patient activities were not sufficiently detailed to accurately identify the specific types of activities that patients were engaged in at the time of injury. Activities were categorised broadly as education, sports or leisure, which may have led to an overestimation of the proportion of patients with SRR-TBI. More granular data on the specific activities involved would have provided a clearer understanding of the circumstances surrounding these injuries.

Lastly, this study was conducted in low-to-intermediate level EMS services across several countries with varying standards of EMS care, which may differ substantially from those in Western EMS settings. As a result, the findings may not be directly applicable to all populations, particularly those in regions with more advanced EMS systems.

CONCLUSION

This study demonstrates that patients with SRR-TBI who receive treatment aimed at maintaining optimal blood pressure and peripheral SpO_2 during EMS care experience better neurological outcomes and survival rates. Conversely, suboptimal management of either SBP or SpO_2 alone did not result in significantly different outcomes compared with suboptimal management of both parameters. These findings underscore the importance of adhering to TBI treatment guidelines for patients with SRR-TBI.

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Contributors JC, SDS and SR had full access to all of the data in the study and took responsibility for the integrity of the data and the accuracy of the data analysis. Study concept and design: JC and SDS. Acquisition, analysis or interpretation of the data: JC and SDS. Drafting of the manuscript: JC, SDS and SR. Critical revision of the manuscript for important intellectual content: JC, SDS, SR, WP and W-CC. Data collection and quality assurance: SDS, SR, WP. Statistical analysis: JC and SDS. Manuscript approval: JC, SDS, SR, WP, W-CC, KK, SFJ and KJS. SDS is the guarantor.

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Competing interests None declared.

Patient consent for publication Not applicable.

Ethics approval The study was approved by the Siriraj Institutional Review Board (certification of approval number 073/2024). Informed consent was waived due to the retrospective nature of the study.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data may be obtained from a third party and are not publicly available. The data that support the findings of this study are available from the PATOS study group. Restrictions apply to the availability of these data, which were used under licence for this study, and so are not publicly available. Data are however available from the authors with the permission of the PATOS.

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REFERENCES

1 Dewan MC, Rattani A, Gupta S, *et al*. Estimating the global incidence of traumatic brain injury. *J Neurosurg* 2019;130:1080–97.
2 Brazinova A, Rehorcikova V, Taylor MS, *et al*. Epidemiology of Traumatic Brain Injury in Europe: A Living Systematic Review. *J Neurotrauma* 2021;38:1411–40.
5 James SL, Theadom A, Ellenbogen RG, *et al*. Global, regional, and national burden of traumatic brain injury and spinal cord injury, 1990–2016: a systematic analysis for the Global Burden of Disease Study 2016. *Lancet Neurol* 2019;18:56–87.
4 Lumba-Brown A, Yeates KO, Sarmiento K, *et al*. Centers for Disease Control and Prevention Guideline on the Diagnosis and Management of Mild Traumatic Brain Injury Among Children. *JAMA Pediatr* 2018;172:e182853.
5 Bayt DR, Bell TM. Trends in paediatric sports-related injuries presenting to US emergency departments, 2001–2013. *Inj Prev* 2016;22:361–4.
6 Theadom A, Mahon S, Hume P, *et al*. Incidence of Sports-Related Traumatic Brain Injury of All Severities: A Systematic Review. *Neuroepidemiology* 2020;54:192–9.
7 Sahler CS, Greenwald BD. Traumatic brain injury in sports: a review. *Rehabil Res Pract* 2012;2012:659652.
8 Spaite DW, Bobrow BJ, Keim SM, *et al*. Association of Statewide Implementation of the Prehospital Traumatic Brain Injury Treatment Guidelines With Patient Survival Following Traumatic Brain Injury: The Excellence in Prehospital Injury Care (EPIC) Study. *JAMA Surg* 2019;154:e191152.
9 Kong SY, Shin SD, Tanaka H, *et al*. Pan-Asian Trauma Outcomes Study (PATOS): Rationale and Methodology of an International and Multicenter Trauma Registry. *Prehosp Emerg Care* 2018;22:58–83.
10 ASEAN Secretariat. ASEAN survey on sports participation 2021 measuring sports' contribution to socio-economic development in 10 cities. Jakarta, 2022. Available: https://asean.org/wp-content/uploads/2022/10/ASEAN-Sports-Participation-Study-2021-screen.pdf
11 Roh SY, Chang IY. Gender, social stratification, and differences in sports participation among Korean adults: data from the 2019 Korea National Sports Participation Survey. *J Mens Health* 2022;18:168.
12 Jung YH, Wi DH, Shin SD, *et al*. Comparison of trauma systems in Asian countries: a cross-sectional study. *Clin Exp Emerg Med* 2019;6:321–9.
13 Shin SD, Hock Ong ME, Tanaka H, *et al*. Comparison of Emergency Medical Services Systems Across Pan-Asian Countries: A Web-based Survey. *Prehosp Emerg Care* 2012;16:477–96.
14 Sun KM, Song KJ, Shin SD, *et al*. Comparison of Emergency Medical Services and Trauma Care Systems Among Pan-Asian Countries: An International, Multicenter, Population-Based Survey. *Prehosp Emerg Care* 2017;21:242–51.
15 Lulla A, Lumba-Brown A, Totten AM, *et al*. Prehospital Guidelines for the Management of Traumatic Brain Injury - 3rd Edition. *Prehosp Emerg Care* 2023;27:507–38.
16 Kim J, Shin SD, Im TH, *et al*. Development and validation of the Excess Mortality Ratio-adjusted Injury Severity Score Using the International Classification of Diseases 10th Edition. *Acad Emerg Med* 2009;16:454–64.
17 Gravesteijn BY, Sewalt CA, Stocchetti N, *et al*. Prehospital Management of Traumatic Brain Injury across Europe: A CENTER-TBI Study. *Prehosp Emerg Care* 2021;25:629–43.
18 Hirschhorn RM, Kerr ZY, Mensch JM, *et al*. Epidemiology of Emergency Medical Services Activations for Sport-Related Injuries in the United States. *Cureus* 2022;14:e27403.
19 Harmon KJ, Proescholdbell SK, Register-Mihalik J, *et al*. Characteristics of sports and recreation-related emergency department visits among school-age children and youth in North Carolina, 2010-2014. *Inj Epidemiol* 2018;5:23.
20 Pélieu I, Kull C, Walder B. Prehospital and Emergency Care in Adult Patients with Acute Traumatic Brain Injury. *Med Sci (Basel)* 2019;7:12.
21 Waltzman D, Thomas S, Sarmiento KE, *et al*. MMWR, Trends in emergency department visits for contact sports–related traumatic brain injuries among children — United States, 2001–2018. vol. 69. 2001. Available: https://surveillance.cancer.gov/joinpoint/
22 Taylor BN, Rasnake N, McNutt K, *et al*. Rapid Ground Transport of Trauma Patients: A Moderate Distance From Trauma Center Improves Survival. *Journal of Surgical Research* 2018;232:318–24.