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Clinical Article

Epidemiology and Outcomes of Severe Traumatic Brain Injury: Regional Trauma Center in Incheon, Korea, 2018–2022

Ik Jun Hwang [1], **Tae Seok Jeong** [2], **Woo Seok Kim** [2], **Jung Ook Kim** [2], and **Myung Jin Jang** [3]

[1]Department of Neurosurgery, Gil Medical Center, Gachon University College of Medicine, Incheon, Korea
[2]Department of Traumatology, Gil Medical Center, Gachon University College of Medicine, Incheon, Korea
[3]Regional Trauma Center, Gil Medical Center, Gachon University College of Medicine, Incheon, Korea

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Address for correspondence:
Tae Seok Jeong
Department of Traumatology, Gil Medical Center, Gachon University College of Medicine, 21, Namdong-daero 774 beon-gil, Namdong-gu, Incheon 21565, Korea.
Email: jeongtaeseok@outlook.com

ORCID iDs
Ik Jun Hwang
https://orcid.org/0009-0004-3258-9048
Tae Seok Jeong
https://orcid.org/0000-0001-5877-0647
Woo Seok Kim
https://orcid.org/0000-0001-9173-4453
Jung Ook Kim
https://orcid.org/0000-0002-6667-6447
Myung Jin Jang
https://orcid.org/0000-0001-5059-0385

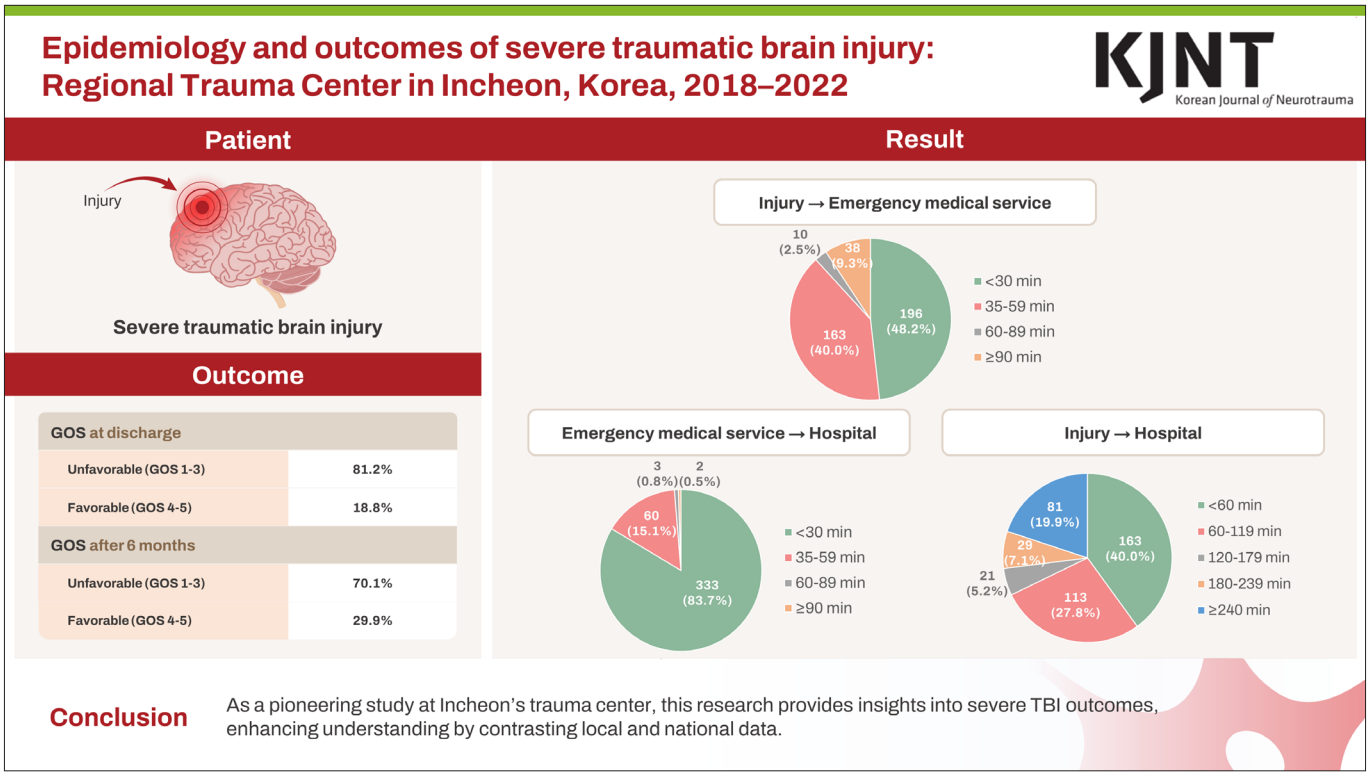
Conflict of Interest
The authors have no financial conflicts of interest.

ABSTRACT

Objective: This study aims to explore the epidemiology and outcomes of severe traumatic brain injury (TBI) in Incheon, focusing on regional characteristics using data from a local trauma center.
Methods: From January 2018 to December 2022, 559 patients with severe TBI were studied. We analyzed factors related to demography, prehospitalization, surgery, complications, and clinical outcomes, including intensive care unit stay, ventilator use, hospital stay, mortality, and Glasgow outcome scale (GOS) scores at discharge and after 6 months.
Results: In this study, most severe TBI patients were in the 60–79 age range, constituting 37.4% of cases. Most patients (74.1%) used public emergency medical services for transportation, and 75.3% arrived directly at the hospital, a significantly higher proportion compared to transferred patients. Timewise, 40.0% reached the hospital within an hour of injury. Complication rates stood at 16.1%, with pneumonia being the most common. The mortality rate was 44.0%, and at discharge, 81.2% of patients had unfavorable outcomes (GOS 1–3), reducing to 70.1% at 6 months.
Conclusion: As a pioneering study at Incheon's trauma center, this research provides insights into severe TBI outcomes, enhancing understanding by contrasting local and national data.

Keywords: Epidemiology; Glasgow coma scale; Mortality; Traumatic brain injury; Trauma centers

GRAPHICAL ABSTRACT



INTRODUCTION

Traumatic brain injury (TBI), which refers to head trauma leading to brain dysfunction, is a global health concern with wide-ranging implications,[8] affecting individuals, families, and healthcare systems worldwide. The study of the epidemiology and outcomes of TBI is vital for developing effective healthcare policies and trauma management protocols, particularly in Korea, which mirrors global trends.

With its high population density and urbanization rate, Incheon presents unique challenges in TBI management. Moreover, the demographic and socioeconomic characteristics of the city potentially influence the prevalence and nature of TBI cases. Therefore, examining TBI in the context of the healthcare resources and infrastructure of Incheon is crucial, providing insights into urban TBI trends and healthcare efficacy.

Despite the global recognition of 'the impact of TBI in the healthcare system and socioeconomic status of a country, comprehensive, region-specific studies regarding the occurrence and management of TBI in Korea are lacking. The existing literature often generalizes or omits local factors crucial to understanding the epidemiology and outcomes of TBI. This study aimed to fill this gap by investigating the regional characteristics and outcomes of patients with severe TBI in Incheon, utilizing data from a regional trauma center. This approach sought to deepen our understanding of 'the impact and management of TBI within this urban context.

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MATERIALS AND METHODS

This retrospective study was approved by the Clinical Research Ethics Review Committee of the Gachon University Gil Medical Center (approval No. GBIRB2023-042). Given its retrospective design, the requirement for informed consent was waived. All procedures adhered strictly to the relevant guidelines and regulatory standards outlined in the Declaration of Helsinki.

Patient selection

Between January 2018 and December 2022, 15,425 patients visited our regional trauma center in Incheon, Korea. Exclusion criteria included: death on arrival, absence of abbreviated injury scale (AIS) head coding, AIS head scores below 3, and Glasgow coma scale (GCS) scores of 9 or above. Ultimately, 559 patients were included in the study.

Data analysis

Data on age, gender, injury mechanisms, initial vital signs, initial pupil response, initial GCS score upon admission to the emergency room, diagnosis, AIS, injury severity score (ISS), revised trauma score (RTS), and trauma and injury severity score (TRISS) were collected for demographic analysis. The evaluated vital signs included blood pressure, pulse rate, respiratory rate, and temperature. The most severe head injury was used as the representative diagnosis. Evaluated diagnoses included subdural hematoma (SDH), epidural hematoma (EDH), intracerebral hemorrhage (ICH), subarachnoid hemorrhage, and diffuse axonal injury. AIS scores were assessed by trauma specialists and coordinators. Finally, ISS, RTS, and TRISS were calculated using the respective equations.[13]

Prehospitalization factors such as arrival route, transport mode, time intervals, surgery-related factors, and postinjury complications were also analyzed. Regarding outcomes, the intensive care unit (ICU) stay and ICU-related ventilator maintenance period, hospital stay, mortality, and Glasgow Outcome Scale (GOS) score at discharge and after 6 months were evaluated, categorizing outcomes as unfavorable (GOS 1–3) or favorable (GOS 4–5).

RESULTS

Characteristics

This study included 559 patients with severe TBI, with an average age of 54.71±19.77 years. The most represented age group was that of 60–79 years, accounting for 37.4% of all cases. The majority of patients were men (75.3%). The number of hospitalized patients by year was the highest at 135 in 2019 and the lowest at 85 in 2021. The most frequent causes of injury included traffic accidents, falls, and slips. Upon initial assessment, elevated systolic blood pressure (mean: 146.3 mmHg) and pulse rate (mean: 97.5 bpm) were noted. More than half of patients (50.8%) exhibited bilateral unreactive pupils. The predominant diagnosis was SDH, observed in 75.3% of patients, followed by EDH and ICH. The mean GCS score was 5.1, indicating severe brain injury. The AIS scores were highest for head injuries (mean: 4.37), whereas scores for other body regions were generally below 2. The mean ISS was 26.99, consistent with severe trauma. Additionally, the mean RTS and TRISS values were 5.02 and 56.02, respectively (**TABLE 1**).

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TABLE 1. Characteristics of patients with severe TBI

Characteristics	Patients with severe TBI (n=559)
Age (years)	54.71±19.77
<20	38 (6.8)
20–39	86 (15.4)
40–59	177 (31.6)
60–79	209 (37.4)
≥80	49 (8.8)
Gender	
Women	138 (24.7)
Men	421 (75.3)
Year of hospitalization	
2018	130 (23.2)
2019	135 (24.2)
2020	94 (16.8)
2021	85 (15.2)
2022	115 (20.6)
Injury mechanisms	
Fall	158 (28.3)
Slip down	105 (18.8)
Struck by person or object	14 (2.5)
Traffic accident	225 (40.3)
Unknown	57 (10.1)
Initial vital sign	
Systolic blood pressure	146.3±42.3
Diastolic blood pressure	89.7±25.6
Pulse rate	97.5±25.6
Respiratory rate	20.5±5.3
Body temperature	35.7±3.9
Initial pupil response	
Reactive	235 (42.0)
Unilateral unreactive	40 (7.2)
Bilateral unreactive	284 (50.8)
Diagnosis	
SDH	421 (75.3)
EDH	60 (10.7)
ICH	41 (7.3)
SAH	23 (4.2)
DAI	14 (2.5)
Injury severity	
GCS	5.1±1.7
AIS	
Head	4.37±0.81
Face	0.53±0.89
Chest	1.13±1.48
Abdomen	0.50±1.02
Extremities	0.86±1.23
External	0.49±0.54
ISS	26.99±9.56
RTS	5.02±0.97
TRISS	56.02±25.82

Values are presented as number (%) or mean ± standard deviation.
TBI: traumatic brain injury, SDH: subdural hematoma, EDH: epidural hematoma, ICH: intracerebral hemorrhage, SAH: subarachnoid hemorrhage, DAI: diffuse axonal injury, GCS: Glasgow coma scale, AIS: abbreviated injury scale, ISS: injury severity score, RTS: revised trauma score, TRISS: trauma and injury severity score.

Factors related to hospital arrival

The majority of patients with severe TBI (75.3%) arrived directly at the hospital, a number approximately 3 times higher than that of patients transferred from other facilities. The primary mode of transportation was public emergency medical services (EMS), used in 74.1%

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of cases. Private ambulance services were the second most common transportation method, accounting for 18.6% of cases. Although less frequent, aeromedical transport and doctor car operated by Incheon City were utilized in 5.3% and 0.7% of cases, respectively (**TABLE 2**).

Time interval

Due to the absence of records on injury time, time intervals were analyzed for patients who used public EMS as a mode of transport. In most cases, the EMS team reached the patient within an hour of the injury. Specifically, 48.2% of patients were reached within 30 minutes and 40.0% between 30 to 59 minutes; however, in 9.3% of cases, it took more than 90 minutes for the responders to reach the patient. Once the EMS team arrived, 83.7% of patients were transported to the emergency room within 30 minutes. Regarding the overall time from injury to hospital arrival, 40.0% of patients arrived within 60 minutes, 27.8% between 60 to 119 minutes, whereas for 19.9% it took more than 240 minutes (**FIGURE 1**).

Factors related to surgery

Surgical procedures were performed in 39.2% of patients with severe TBI. The predominant surgery was craniectomy, accounting for 76.7% of all surgeries, followed by craniotomy, external ventricular drain, and burr-hole procedures. The average duration of these surgeries was approximately 142.6 min, and the estimated average blood loss was approximately 1,035.9 mL (**TABLE 3**).

Postinjury complications

Complications following injury were reported in 16.1% of patients with severe TBI. Pneumonia was the most frequent complication, affecting 14.0% of patients. In addition,

TABLE 2. Factors related to hospital arrival

Factors	Patients with severe TBI (n=559)
Route of arrival	
Direct	421 (75.3)
Transfer	138 (24.7)
Mode of transport	
Public EMS	414 (74.1)
Private ambulance service	104 (18.6)
Aeromedical transport	30 (5.3)
Other hospital ambulance	7 (1.3)
Doctor car	4 (0.7)

Values are presented as number (%).
TBI: traumatic brain injury, EMS: emergency medical service.

TABLE 3. Factors related to surgery

Factors	Patients with severe TBI (n=559)
Surgery	
Yes	219 (39.2)
No	340 (60.8)
Type of surgery	
Craniectomy	168 (76.7)
Craniotomy	34 (15.5)
EVD	14 (6.4)
Burr-hole	3 (1.4)
Surgery time (minute)	142.6±62.2
Estimated blood loss (mL)	1,035.9±933.9

Values are presented as number (%).
TBI: traumatic brain injury, EVD: external ventricular drain.

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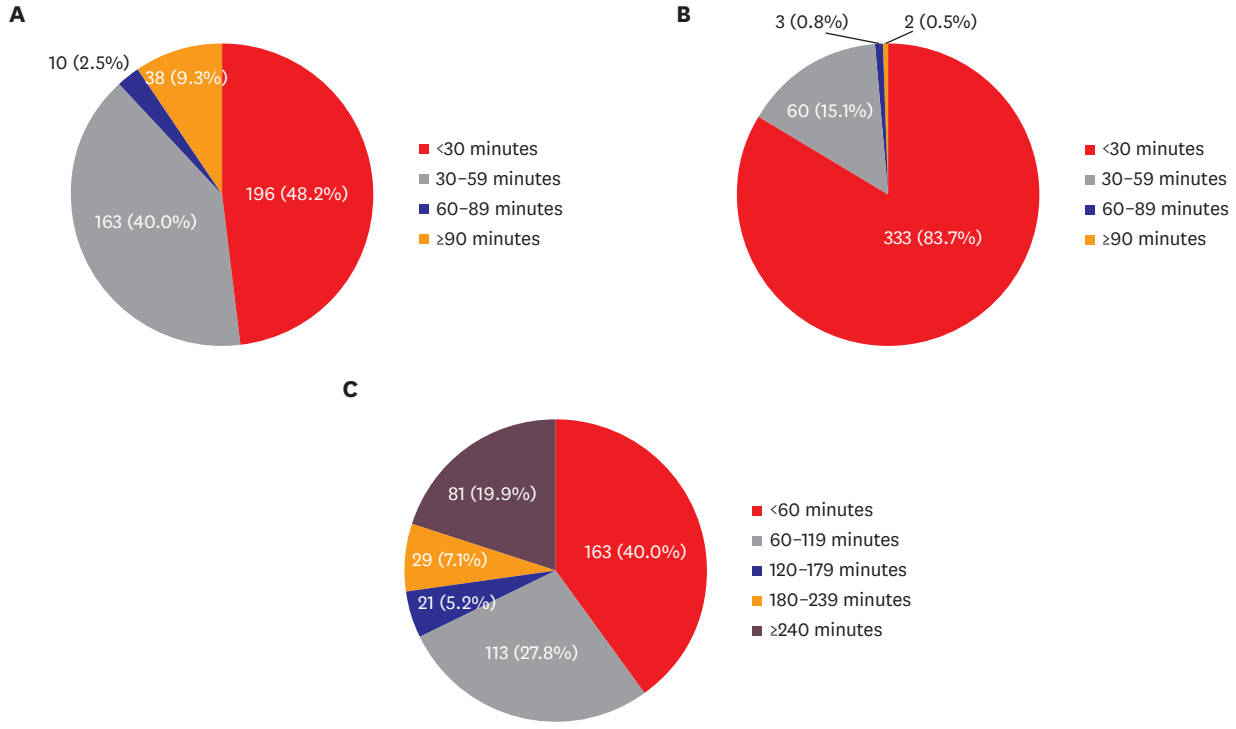

FIGURE 1. Time intervals: (A) from injury to arrival of the emergency medical services team, (B) from arrival of the emergency medical services team to hospital arrival, and (C) total time from injury to hospital arrival.

acute kidney injury (AKI) and deep vein thrombosis (DVT) were among the most notable complications observed in this patient group (**TABLE 4**).

Outcomes

Regarding the intensive care treatment of patients with severe TBI, the study recorded an average ICU stay of 12.5 days and a ventilator maintenance period of 7.9 days. The average hospital stay was 24.8 days. The mortality rate among these patients was 44.0%. Moreover, a high rate of unfavorable outcomes (GOS 1–3) was observed, accounting for 81.2% of patients at discharge and decreasing to 70.1% at the 6-month follow-up (**TABLE 5**).

TABLE 4. Postinjury complications

Characteristics	Patients with severe TBI (n=559)
Complications	
Yes	90 (16.1)
No	469 (83.9)
Types of complications	
AKI	10 (1.8)
ARDS	4 (0.7)
DVT	8 (1.4)
Pneumonia	78 (14.0)
PTE	3 (0.5)
Sepsis	5 (0.9)

Values are presented as number (%).
TBI: traumatic brain injury, AKI: acute kidney injury, ARDS: acute respiratory distress syndrome, DVT: deep vein thrombosis, PTE: pulmonary thromboembolism.

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TABLE 5. Outcomes

Characteristics	Patients with severe TBI (n=559)
ICU stay (day)	12.5±15.3
Ventilator maintenance period (day)	7.9±13.3
Hospital stay (day)	24.8±25.9
Death at discharge	
Yes	246 (44.0)
No	313 (56.0)
GOS at discharge	
Unfavorable outcome (GOS 1–3)	454 (81.2)
Favorable outcome (GOS 4–5)	105 (18.8)
GOS after 6 months	
Unfavorable outcome (GOS 1–3)	392 (70.1)
Favorable outcome (GOS 4–5)	167 (29.9)

Values are presented as number (%) or mean ± standard deviation.
TBI: traumatic brain injury, GOS: Glasgow outcome scale, ICU: intensive care unit.

DISCUSSION

The average age of patients with severe TBI was 54 years, with the highest incidence in the 60–79 years age group at 37.4%, followed by the 40–59 years age group at 31.6%. According to Korea's demographic statistics announced by the Ministry of the Interior and Safety in December 2023,[18,19] the 50–59 years age group constitutes 17.2% of the total population of Incheon, followed by the 40–49 years age group at 16.0%. In addition, the 40–59, 20–39, and 60–79 years age groups represent 33%, 26%, and 21% of the total population of Incheon, respectively. The high incidence of severe TBI in the 40–59 age group aligned with the age distribution in Incheon. However, the 60–79 age group showed a relatively high incidence of severe TBI (37.4%) relative to its population percentage (21%), possibly due to increased risk of falls associated with age-related decline in muscle strength and reflexes. This trend was even more pronounced in the over-80 age group, where despite only making up 3% of the population, they accounted for 8.8% of accident cases, indicating a significantly higher incidence relative to their population proportion compared with that of other age groups.

In Incheon, the gender ratio in the population is evenly split between men and women.[18] However, the incidence of severe TBI in men was approximately 3 times higher than that in women. This disparity may have been influenced by factors such as occupational types and alcohol consumption rates; however, due to a lack of specific data, the exact causes remain unclear.

The number of hospitalized patients by year showed a sharp decline in 2020 and 2021 but then increased again in 2022. It is thought to be related to coronavirus disease 2019 (COVID-19). Previous studies have reported a decrease in the overall number of trauma patients due to a decrease in non-essential activities during the COVID-19 pandemic,[15,25] and this study also showed similar results.

In this study, the most common injury mechanisms for severe TBI were traffic accidents, followed by falls. This aligned with the findings by Jeong et al.[12] from their 2018–2021 national survey on severe TBI. They reported that trauma centers predominantly attended to cases of traffic accidents and falls as injury mechanisms, whereas nontrauma centers had more cases of slip-downs, followed by traffic accidents. The similarity between the results of this study and the national data on trauma centers suggested the existence of an appropriate

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categorization of patients based on injury mechanisms between trauma and nontrauma centers, at least in the Incheon region.

Although comparing our results with data from hospitals nationwide was not possible due to the lack of trauma score data from nontrauma centers, the injury severity assessed using the GCS and trauma scoring systems in this study showed no significant differences from the results of trauma centers nationwide.[13]

Regarding the hospital arrivals of patients with severe TBI, direct admissions, primarily via public EMS, were the most common. Transfers often involved private ambulance services due to limitations in the use of public EMS in the Korean emergency medical system. Incheon has been operating a doctor helicopter since 2011, with emergency medical specialists providing care during the transport of patients from remote areas. Currently, 8 hospitals nationwide use helicopters as a vital part of their emergency transport system. Unique to Incheon since 2019 is the operation of a doctor car, where trauma surgeons and nurses respond directly to emergency scenes.[1] This service is mainly used for severe trauma patients with significant bleeding, and in this study, all 4 cases using the doctor car involved polytrauma patients with substantial bleeding.

Postinjury complications occurred in approximately 16% of patients with severe TBI, with pneumonia, AKI, and DVT being the most common. Prolonged bedridden states and ventilator use in patients with severe TBI likely contribute to the higher rates of pneumonia and DVT.[4,24] In polytrauma patients, AKI can result from causes such as shock-induced renal ischemia and rhabdomyolysis.[7] Moreover, factors such as hypernatremia and osmotic therapy may increase AKI risk in patients with TBI.[24] Considering that these complications significantly affect outcomes, careful monitoring and proactive preventive measures are crucial.

In this study, the mortality rate for patients with severe TBI was 44%, matching the expected survival rate of 56% as indicated by TRISS. Moreover, after 6 months, 70% of patients showed unfavorable outcomes as measured by GOS. Interestingly, a review of 15 previous studies on severe TBI outcomes revealed considerable variability: 21%–79% for mortality and 41%–85% for unfavorable outcomes, with an overall average of 43.6% for mortality and 52.9% for unfavorable outcomes.[2,3,5,6,9-11,14,16,17,20,21,23,26] Compared with the findings of the abovementioned studies, our study found no significant difference in mortality rates for severe TBI cases. However, the rate of unfavorable outcomes in our study was higher than that reported in these studies, also exceeding the 72.7% rate of unfavorable outcomes reported for trauma centers nationwide in Korea by Jeong et al.[12] These comparisons, while not exact due to differences in patient cohorts among studies, highlight the need for improved treatment guidelines and emergency medical policies to enhance favorable outcomes in patient with TBI.

For trauma patients, including those with head injuries, the EMS system is crucial for securing the “golden time,” which is the critical period immediately following an injury. The EMS system is designed to provide swift and effective medical services in emergencies. It is divided into 2 main stages based on the location of care: the prehospital and inhospital stages. The prehospital phase includes emergency medical communication systems and ambulance services, whereas the inhospital phase encompasses medical institutions such as emergency and trauma centers, specialized emergency medical personnel, and emergency treatments. Effective implementation and operation of the EMS system require collaboration among governments, local authorities, medical institutions, ambulance services,

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communities, and research and education institutions.[22] In 2020, Incheon initiated a pilot project to establish a regional trauma care system. This project involves the collaboration among the Incheon city council, fire headquarters, coast guard, Incheon research institutes, regional trauma centers, emergency medical institutions, and private transportation companies. The aim was to establish a regional trauma governance system to reduce preventable trauma death rates by ensuring timely and appropriate transport and referral of trauma patients. If this trauma system in the Incheon area is effectively and well-organized, a significant improvement in the outcomes of trauma patients, including those with severe TBI is expected in the future.

This study had several limitations. First, its focus on a single trauma center may not fully represent the characteristics of patients with severe TBI across the entire Incheon region. Further analysis incorporating data from local emergency medical centers is needed to address this. Second, the method of extracting postinjury complication data based solely on disease codes may have led to the underestimation of complication incidences. Third, the inability to analyze data on accident locations limited our insights into the unique challenges of the geographical characteristics of the Incheon island area and its emergency transport system. In addition, the importance of time interval analysis is emphasized because "golden time" is crucial to TBI patients. Still, because injury time was recorded only when public EMS was used as a mode of transport, it was impossible to analyze the time from injury to hospital arrival by transportation method. Future data collection efforts in collaboration with emergency services are crucial. Finally, this study did not evaluate factors such as prehospital management, TBI management strategies, and brain computed tomography (CT) findings, including the Rotterdam CT score, which are vital in assessing TBI outcomes. Future research should aim to analyze these factors to better understand their impact on TBI outcomes.

CONCLUSION

As the inaugural research effort at the regional trauma center in Incheon, this study explored the epidemiology and outcomes of patients with severe TBI. Despite data limitations, it offered valuable insights regarding TBI outcomes by comparing local data with national statistics. Future research focusing on periodic assessments of severe TBI and incorporating additional data, particularly from the prehospital stage, is anticipated to enhance the functionality of emergency medical and trauma systems in Incheon and improve outcomes for patients with severe TBI.

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