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The Efficacy of Traumatic Brain Injury Treatment by Neurotrauma Specialists

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

ABSTRACT

Objective: Since the establishment of Regional Trauma Centers (RTCs) in Korea, significant efforts have been made to improve the quality of care for patients with trauma. Simultaneously, the Department of Neurosurgery assigned neurotrauma specialists to RTCs to provide specialized care to patients with traumatic brain injury (TBI). In this study, we sought to determine whether neurotrauma specialists, compared to general neurosurgeons, could make a significant difference in treatment outcomes of patients with TBI.
Methods: In total, 156 patients with acute TBI who required decompression were included. We reviewed their records and compared the characteristics, outcomes, and prognosis of those who received surgical treatment from either neurotrauma specialists or general neurosurgeons at our institution.
Results: A significant difference was observed between treatment by trauma neurosurgery specialists and general neurosurgeons in time to surgery, with trauma specialists experiencing shorter surgical delays. However, no significant differences existed in mortality rates or Extended Glasgow Outcome Scale scores. Univariate and multivariable regression analyses revealed that lower Glasgow Coma Scale scores, an abnormal pupil reflex, larger transfusion volume, and prolonged time from emergency room admission to surgery were associated with high mortality rates.
Conclusion: Neurotrauma specialists can provide prompt surgical treatment to patients with TBI compared to general neurosurgeons. Our study did not reveal a significant difference in outcomes between the two groups. However, it is clear that rapid decompression is effective in patients with impending brain herniation. Therefore, the effectiveness of neurotrauma specialists needs to be confirmed through further systematic studies.

Keywords: Traumatic brain injury; Neurotrauma specialist; Trauma center; Neurosurgery; Neurosurgeons

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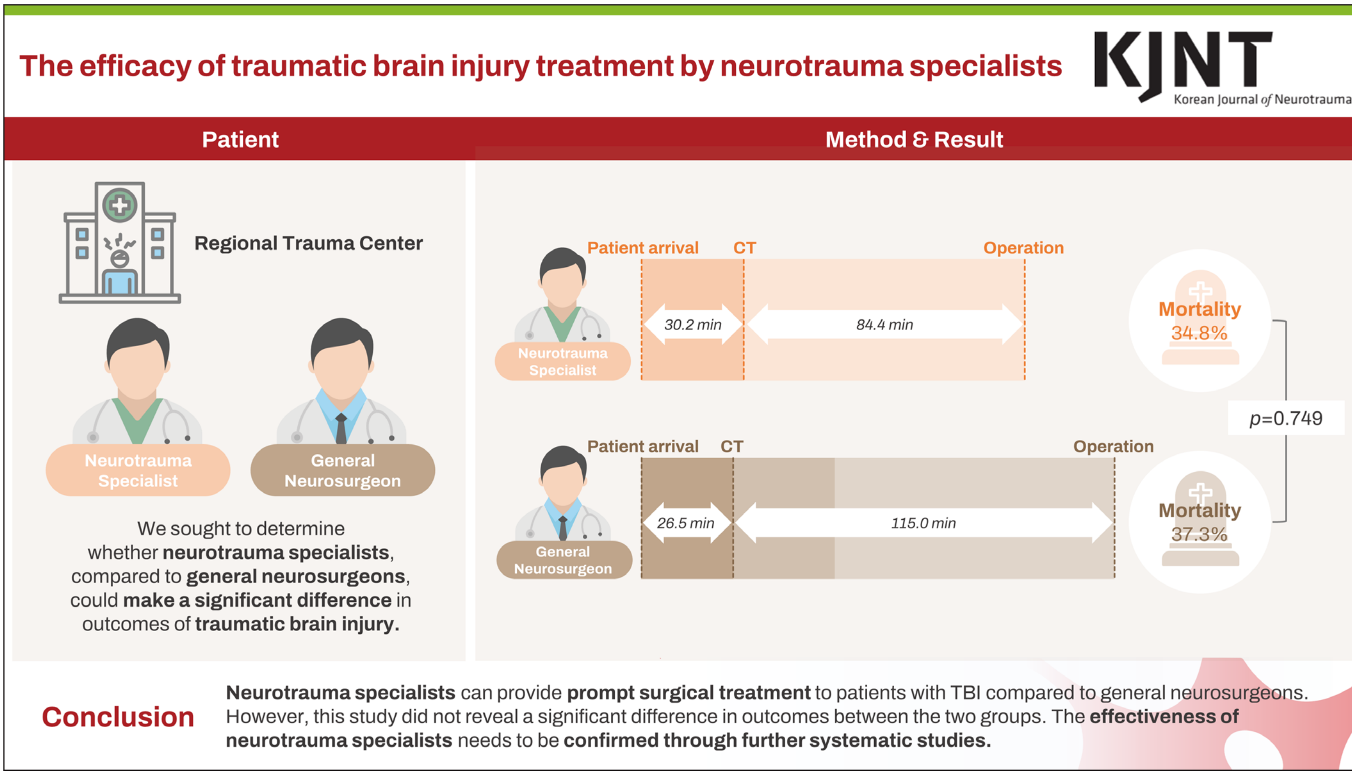
GRAPHICAL ABSTRACT



INTRODUCTION

In 2021, traumatic brain injuries (TBIs) accounted for a high proportion of outpatient and inpatient cases in South Korea (82,444 individuals). According to the Korean Disease Control and Prevention Center, these constituted 36.4% and 41.9% of all trauma outpatient and inpatient cases, respectively. Furthermore, the number of mortalities due to TBIs was 1,789 cases, accounting for 69.9% of all trauma-related fatalities. Since the establishment of Regional Trauma Centers (RTCs) in Korea in 2014, neurotrauma specialists have been placed in neurosurgery departments in university hospitals, academic research has been encouraged, and conferences have been held to improve the quality of care for trauma patients and reduce mortality rates. Although the establishment of RTCs helped reduce the preventable death rate, mortality remains high. Simultaneously, the Department of Neurosurgery assigned trauma specialists to RTCs to provide specialized care to patients with traumatic brain injury (TBI). In this study, we sought to determine whether neurotrauma specialists, compared to general neurosurgeons, could make a significant difference in treatment outcomes of patients with TBI.

We reviewed the clinical charts of patients with TBI who received surgical treatment from neurotrauma specialists or general neurosurgeons. We analyzed the characteristics of both groups and investigated differences in their prognoses.

MATERIALS AND METHODS

Patient selection

We reviewed the medical charts of patients diagnosed with TBI at our institution between January 2020 and October 2022. We identified 181 patients diagnosed with TBI using initial brain computed tomography (CT) who underwent immediate surgical treatment (**FIGURE 1**). Among these patients, nine with chronic hematoma, two with hydrocephalus, and 14 with skull fractures were excluded. Therefore, 156 patients with acute TBI and high intracranial pressure (ICP) who required decompression were included in our study. All patients received prehospital care and initial neuroprotective management according to the Korean Guidelines for the Management of Severe Head Injuries.[3] Two neurotrauma specialists and six general neurosurgeons treated the patients with neurotrauma to compare the prognostic factors of hemorrhage caused by acute TBI. To compare mortality rates between the two groups, all-cause death was included.

At our institution, as soon as a trauma patient arrives at the emergency room, neurotrauma specialists directly examine the patient and prescribe a brain CT. However, if a general neurosurgeon is on duty, many complicated steps must be taken. When a trauma patient arrives at the emergency room, an emergency medicine doctor evaluates the patient and prescribes a brain CT. If intracranial hemorrhage is confirmed, a report is made to the general neurosurgeon through the resident of neurosurgery.

This study was conducted in accordance with the Declaration of Helsinki and approved by the local ethics committee (2023-10-010). The requirement for informed consent was waived owing to the retrospective nature of this study.

Surgical indication

All patients preoperatively underwent CT in the emergency room immediately after checking their vital signs and receiving basic treatment. The indications for surgery were decreased mentality with a Glasgow Coma Score (GCS) score of ≤8 points, midline shift of >5 mm, extradural hematoma thickness of >15 mm, subdural hematoma thickness of >10 mm,

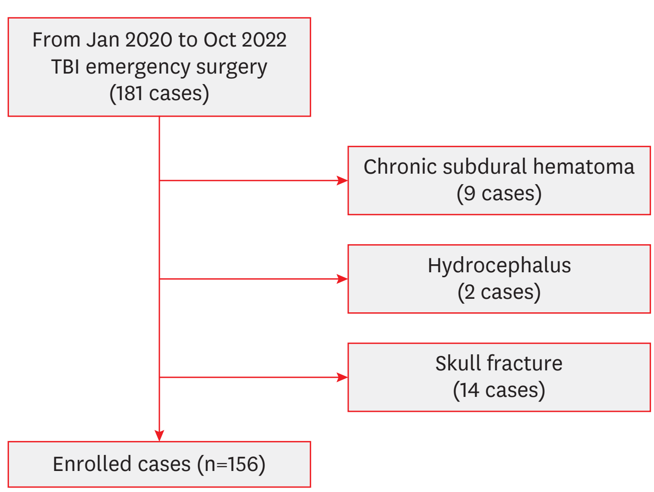


FIGURE 1. Flow diagram illustrating patient selection.
TBI: traumatic brain injury.

markedly increased hemorrhage compared to previous CT in the case of transfer, or rapid mental change in the emergency room.[3]

Statistical analysis

Student t-tests and Chi-square tests were used to compare differences in age, sex, pupil reflex abnormalities on admission (indicating brain herniation), Rotterdam CT score, GCS score, diagnosis, hematoma location, time from emergency room admission to start of surgery, time from CT imaging to start of surgery, Glasgow Outcome Scale (GOS), and mortality between both groups. Injury severity score (ISS) was calculated according to the Abbreviated Injury Scale Committee of the Association for the Advancement of Automotive Medicine. Additionally, univariate and multivariable regression analyses were conducted on mortality rates, considering the variants mentioned above as prognostic indicators. IBM SPSS Statistics package version 25 (IBM Corp., Armonk, NY, USA) was used for statistical analysis.

RESULTS

Demographics

The patients' mean age was 59±18.0 years; there were 33 (21.2%) women, and 123 (78.8%) men. The average ISS score was 30.4±6.7, while the average GCS score was 8.2±4.0. Seventy-three patients (46.8%) had abnormal pupillary reflexes. Subdural hematoma was observed in 93 (59.6%) patients, epidural hematoma in 43 (27.6%), and intracerebral hematoma in 9 (5.8%). Complex lesions occurred in 11 patients (7.1%), right side lesions in 68 (43.6%), left side lesions in 63 (40.4%), bilateral lesions in 17 (10.9%), and cerebello-occipital lesions in 8 (5.1%) patients. The average Rotterdam score was 4.7±1.3. Eighty-nine (57.1%) patients were treated on admission by neurotrauma specialists (**TABLE 1**).

Comparing the patients in the neurotrauma specialist and general neurosurgeon groups, no differences were observed in age, sex, GCS, pupil reflex, hemorrhage diagnosis or location, Rotterdam CT score, transfusion volume, GOS, and mortality. However, a significant

TABLE 1. Demographics and neurological status at admission

Variables	Values (n=156)
Age (years)	59.2±18.0
Sex	
Female	33 (21.2)
Male	123 (78.8)
Injury Severity Score	30.4±6.7
Glasgow Coma Scale	8.2±4.0
Abnormal pupil reflex	73 (46.8)
Diagnosis	
Subdural hematoma	93 (59.6)
Epidural hematoma	43 (27.6)
Intracerebral hematoma	9 (5.8)
Complex	11 (7.1)
Location	
Right	68 (43.6)
Left	63 (40.4)
Bilateral	17 (10.9)
Cerebello-occipital	8 (5.1)
Rotterdam score	4.7±1.3
Admission to neurotrauma specialist	89 (57.1)

Data are shown as mean ± standard deviation or number (%).

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TABLE 2. Operative variables and patient outcomes

Variables	Values (n=156)
Time from emergency room to operation (minutes)	126.1±46.4
Time from CT scan to operation (minutes)	97.6±42.0
Operation time (minutes)	139.4±61.0
Intraoperative transfusion volume (L)	4.4±4.1
Estimated blood loss (L)	2.0±2.2
Glasgow Outcome Scale	
1	56 (35.9)
2	20 (12.8)
3	17 (10.9)
4	23 (14.7)
5	40 (25.6)
Mortality	56 (35.9)

Data are shown as mean ± standard deviation or number (%).
CT: computed tomography.

difference in the time to surgery was observed between neurotrauma specialists and general neurosurgeons, with the former having shorter surgical delays (**TABLE 2**). The time from arrival at the emergency room to initiating surgery and time from CT scan to initiating surgery were 114.6 and 84.4 minutes, respectively, for neurotrauma specialists and 141.5 and 115.0 minutes, respectively, for general neurosurgeons (**FIGURE 2**).

Regarding patients' entire surgical and outcome index, the average time from arrival at the emergency room to the operation room was 126.1±46.4 minutes, while that from the CT scan to initiating the surgery was 97.6±42.0 minutes. The operation time was 139.4±61.0 minutes, and the intraoperative packed red blood cell volume was 4.4±4.1 L, with an estimated blood loss of 2.0±2.2 L (**TABLE 3**).

Predictor of outcome Univariate regression analyses revealed associations between higher mortality rates and lower initial GCS scores, abnormal pupil reflex, hematoma type and location, higher Rotterdam CT score, higher intraoperative transfusion volume, and prolonged time from the emergency room to surgery (**TABLE 4**). With these variants, we conducted a multivariable analysis of mortality.

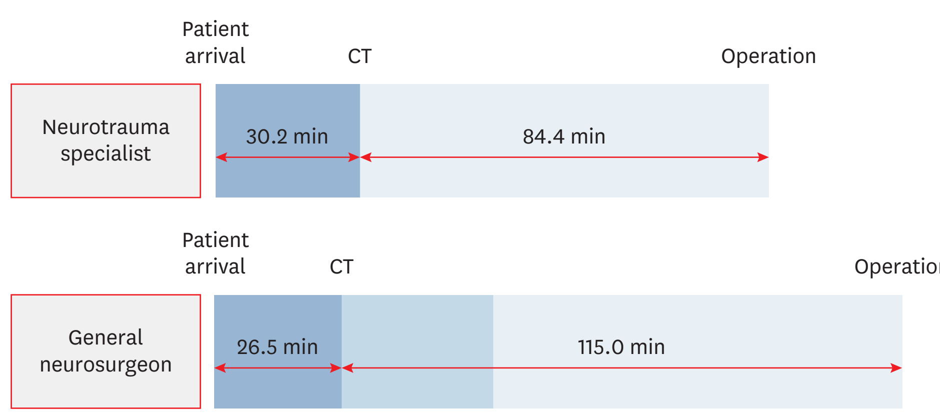

FIGURE 2. Time taken to initiate surgery for a patient with traumatic brain injury.
CT: computed tomography.

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TABLE 3. Comparison between neurotrauma specialist and general neurosurgeon groups

Variables	Classification		p-value
	Neurotrauma specialist (n=89)	General neurosurgeon (n=67)	
Sex			0.743
Female	18 (20.2)	15 (22.4)	
Male	71 (79.8)	52 (77.6)	
Age	60.9±17.2	56.8±18.9	0.152
Glasgow Coma Scale	8.5±3.9	7.8±4.1	0.301
Abnormal pupil reflex	41 (46.1)	32 (47.8)	0.834
Diagnosis			0.860
Subdural hematoma	53 (59.6)	40 (59.7)	
Epidural hematoma	23 (25.8)	20 (29.9)	
Intracerebral hematoma	6 (6.7)	3 (4.5)	
Complex	7 (7.9)	4 (6.0)	
Location			0.482
Right	40 (44.9)	28 (41.8)	
Left	32 (36.0)	31 (46.3)	
Bilateral	12 (13.5)	5 (7.5)	
Cerebello-occipital	5 (5.6)	3 (4.5)	
Rotterdam score	4.6±1.3	4.8±1.3	0.309
Intraoperative transfusion volume (L)	4.0±3.9	5.0±4.4	0.114
Time from emergency room to operation (minutes)	114.6±52.0	141.5±32.1	<0.001*
Time from CT scan to operation (minutes)	84.4±44.0	115.0±31.8	<0.001*
Favorable outcome (GOS>6)	29 (32.6)	23 (34.3)	0.819
Mortality	31 (34.8)	25 (37.3)	0.749

Data are shown as mean ± standard deviation or number (%).
*p-value less than 0.05.

TABLE 4. Univariate and multivariate regression analyzes to determine factors affecting mortality rate

Variables	Univariable		Multivariable	
	OR (95% CI)	p	OR (95% CI)	p
Sex				
Female	1.000 (-)	-		
Male	0.728 (0.318–1.665)	0.452		
Age	1.010 (0.991–1.029)	0.285		
Glasgow Coma Scale	0.619 (0.527–0.728)	<0.001*	0.697(0.559–0.869)	0.002**
Abnormal pupil reflex	14.863(6.407–34.482)	<0.001*	4.429(1.226–16.006)	0.015**
Diagnosis				
Subdural hematoma	1.000 (-)	0.009*	1.000 (-)	0.461
Epidural hematoma	0.197 (0.076–0.511)	0.001*	0.455 (0.089–2.317)	0.343
Intracerebral hematoma	0.607 (0.143–2.575)	0.498	0.634 (0.089–4.501)	0.648
Complex	1.012 (0.288–3.550)	0.985	0.186 (0.018–1.978)	0.163
Location				
Right	1.000 (-)	0.032*	1.000 (-)	0.182
Left	1.119 (0.537–2.332)	0.764	0.917 (0.309–2.721)	0.877
Bilateral	5.371 (1.678–17.190)	0.005*	5.713 (1.037–31.465)	0.045**
Cerebello-occipital	0.746 (0.139–4.007)	0.733	1.094 (0.075–16.008)	0.948
Rotterdam score	2.034 (1.454–2.844)	<0.001*	1.147 (0.553–2.382)	0.712
Intraoperative transfusion volume (L)	1.461 (1.286–1.660)	<0.001*	1.333 (1.162–1.531)	<0.001**
Time from emergency room to operation (minutes)	0.965 (0.629–1.480)	0.870	2.096 (1.087–4.039)	0.027**
Admission to neurotrauma specialist	1.114 (0.576–2.154)	0.749		

SE: standard error.
*p-value less than 0.10 in univariate regression analysis
**p-value less than 0.05 in multivariate regression analysis

DISCUSSION

Several studies have discussed low GCS scores, abnormal pupillary reflexes, and poor CT findings (Rotterdam CT score) as poor prognostic factors in patients with TBI. Previously, pupil dilatation in severe TBI was caused by compression of the third cranial nerve and brain stem as uncal herniation due to brain edema or mass lesion. Ritter et al.[20] reported that significant differences in brain stem blood flow in patients with TBI caused stem ischemia, resulting in poor outcomes. Emami et al.[4] explained the poor outcome associated with GCS and pupil reflex through a retrospective multicenter cohort study. Majdan et al.[12] demonstrated a significant correlation in a univariate and multivariable study of 6-month outcomes. Furthermore, the Rotterdam CT score has recently been considered a major prognosis predictor and is valid at least 3 months after injury.[1,9-11]

Additionally, in the univariate and multivariable analyses, a higher packed red blood cell transfusion volume was associated with worse outcomes. According to Komurcu et al.,[10] no significant correlation exists between transfusion and outcome; however, the Revised Trauma Score was significant. According to Haselsberger et al.,[8] this is because the hemodynamic instability of TBI deteriorates with respect to the outcome of TBI prognosis. Moreover, no significant correlation between low hemoglobin levels and outcomes has been reported.[13,14] Furthermore, acute lung injury, longer intensive care unit and hospital stays, and mortality can accompany red blood cell transfusion. Therefore, blood transfusion is recommended when hemoglobin levels are <10 g/dL, but not for moderate-to-severe TBI.[15,16]

Our RTC was not evaluated for combined lesions because accurate ISS measurements were not preserved. Moreover, because the initial hemoglobin level was not included, this value could not be directly correlated with the above study results. However, the transfusion volume and poor outcomes suggested that the complications of combined lesions that required transfusion negatively affected the patient's prognosis as well as the transfusion.

Several studies have extensively discussed the adverse impact of time delay on mortality.[2,5-7,17] Specifically, a shorter time interval between neurological deterioration and CT scan or incision is associated with more favorable outcomes and reduced mortality.[2,5-7,18] This positive effect is attributed to the prevention of secondary damage, such as acute hemorrhage-induced increase in ICP, pressure-induced ischemia, and brain herniation, through prompt decompression.[21-23] However, studies that considered the time interval from the time of injury to the incision did not uncover significant associations, which could be characteristic of TBI with a higher incidence of combined injuries leading to selection bias.[6,19,20] Accurately measuring the starting point of clinical deterioration is challenging; hence, to improve patient outcomes, time intervals from prehospital and emergency department arrival to CT scan and from CT scan to skin incision should be indirectly reduced.[6,7] Optimization of prehospital notification systems through the RTC, faster transfer or transport such as doctor helicopters, trauma team activation systems for vital sign stabilization such as prompt emergency blood transfusions during initial management, and shortened time from CT scan to the skin incision performed by a neurotrauma specialist can significantly impact patient outcomes by reducing time delays.

In our study, the time to surgical treatment differed significantly between the neurotrauma specialist and general neurosurgeon groups (114.6 minutes vs. 141.5 minutes). The 26.9 minutes difference may be because the neurotrauma specialist directly assesses the patient's condition and quickly decides on treatment without consulting a resident. Nevertheless, the reason why there was no difference in outcome between the two groups is as follows: first, heterogeneity of TBI. Second, small sample size of our study. Third, 26.9 minutes is not enough to make a difference in the results. However, because it is clear that rapid decompression is an important prognostic factor in patients with increased ICP,[2,5-7,22-24] if further systematic studies are conducted with a larger sample size, the effectiveness of neurotrauma specialists could be demonstrated more clearly.

This retrospective analysis revealed that time delay is a crucial prognostic factor in the target patient group. However, a simple t-test did not uncover a significant difference in mortality between the neurotrauma specialist and general surgeon groups. This was attributed to the small sample size. Hence, when patients were transferred from other hospitals, the time delay from injury to the emergency room at our hospital was not considered. Moreover, this study did not consider oxygenation and hemodynamic parameters at the initial emergency room arrival, which are important for neurological outcomes. Another limitation is that the trauma ISS, an important prognostic factor in patients with TBI, was not analyzed as a major factor. Data, including the ISS score, were not accurately preserved at our RTC. Furthermore, as mentioned above, the sample size was insufficient. No significant results were observed; therefore, they were excluded from the analysis.

CONCLUSION

Compared with general neurosurgeons, neurotrauma specialists can provide prompt surgery. Although this study did not reveal a significant difference in outcomes between the two groups, it is clear that rapid decompression is effective in patients with impending brain herniation. Therefore, the effectiveness of neurotrauma specialists needs to be confirmed through further systematic studies.

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