

Clinical Article



Treatment Experiences of Traumatic Brain Injury Patients using Doctor-Helicopter Emergency Medical Service: Early Data in a Regional Trauma Center

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Conflict of Interest

The authors have no financial conflicts of interest.

ABSTRACT

Objective: The purpose of this study is to analyze the results of doctor helicopter emergency medical service (HEMS) in traumatic brain injury (TBI) patients and to understand the effect and improvement of doctor HEMS.

Methods: We included TBI patients transferred by doctor HEMS of our hospital between February 2016 and December 2017. Basic characteristics, HEMS data, treatment and results data were analyzed retrospectively. We divided the patients into 3 groups as regarding severity of patient, relevance of treatment and transfer. We investigated the preventable trauma death rate (PTDR) of these groups to increase the reliability of the treatment outcome.

Results: TBI patients using doctor HEMS were indicated in 98 patients (18.7%) among 522 overall HEMS patients. The overall mortality was consisted in 21.4% and 43.2% was resulted in Glasgow outcome scale 4 or 5. The group of proper transport and treatment for severe TBI was consisted in 62.2% including 13 mortality cases and no preventable death. The group of delayed transport or treatment for severe TBI was 18.3% including 8 mortality cases and 1 preventable death. The PTDR of TBI after doctor HEMS was significantly lower than that of overall TBI (4.8% vs. 11.6%, $p=0.045$).

Conclusion: In patients with severe TBI, doctor HEMS can improve treatment outcomes by reducing treatment delay and unnecessary examinations and this result was evidenced that the PTDR were decreased significantly after doctor HEMS transport. The appropriate treatment is mandatory for real-time communication with the emergency doctor and treatment preparation of the trauma team during the HEMS transport.

Keywords: Emergency medical service; Brain injuries; Glasgow Outcome Scale; Injury Severity Score

INTRODUCTION

In South Korea, helicopter emergency medical services (HEMSs) provided by doctor (so called doctor HEMS or physician staffed air ambulances) team have been used in seven regional trauma centers (RTCs) which supported entirely by public fund of health service of government since 2011. The doctor HEMS team of our hospital, which was formed in February 2016, has so far played a significant role in the transportation of patients to emergency medical center within our regional area.

The National Trauma Data Bank (NTDB) has been used to demonstrate the superiority of air transport (HEMS) over ground emergency medical service (GEMS) for patients with general trauma.^{5,8,15,16)} These analyses, however, have not focused on the subgroup of neurosurgical patients with traumatic brain injury (TBI).

The purpose of this study is to analyze the results of doctor HEMS transport in neurosurgical patients, especially focused on TBI and to understand the effect and improvement of doctor HEMS transport.

MATERIALS AND METHODS

Patient population and clinical data

A retrospective analysis was conducted on all patients who were transported using doctor HEMS in a single emergency medical center between February 2016 and December 2017. Inclusion criteria in this study were to satisfy both the doctor HEMS transport and neurosurgical diagnosis, in which if the patients have multiple injuries, we allowed the main diagnoses. Analysis categories are the following criteria: Basic characteristics are including age, sex, diagnosis, head Abbreviated Injury Scale (AIS), Injury Severity Score (ISS), Glasgow Coma Scale (GCS). Also, HEMS data consist of record including flight time, vital sign with neurologic sign and procedure (intubation, line access, oxygen supply) during transport. Treatment data, including operation, procedure, trauma activation, transfusion and initial resuscitation were also analyzed. Overall mortality, Glasgow Outcome Scale (GOS) at 6 months, and preventable trauma death rate (PTDR) were the primary outcomes evaluated in this study using a multidisciplinary panel review.

Grouping for traumatic brain injury patient by triage, severity, transport timing and treatment adequacy

We divided from 3 groups by following: severity of TBI, transport timing and treatment adequacy. The reason for this classification is to include both the importance of selecting appropriate patients (triage) and the importance of transport timing and the importance of patient treatment after transport due to the limitations of helicopter transport. To evaluate trauma severity, ISS, which is a commonly used standard for anatomical injury, was employed. Moreover, the degree of injury was determined using the initial GCS scores, status of consciousness, and pupil response to confirm the neurological deficit. Severe TBI was defined as having an AIS head score >4 or GCS score of <8 with the need to undergo surgery. The appropriateness of the transport timing was defined as the case where the HEMS transport was made without delay in accordance with trauma guidelines following the initial resuscitation and basic examination in first hospital. Most of these cases are within 2 hours of total transport time. In addition, treatment adequacy was defined as the case where surgical or medical treatment was performed without numerous reasons of treatment delay, including lack of operating room, or intensive care unit and trauma specialist, following the specific examinations in final hospital.

Helicopter transport protocol and criteria for preventability of trauma death

The doctor HEMS team of our hospital consists of emergency medical doctors, nurses and paramedics, and maintains it with public fund of health service of government. The dispatch time of the doctor HEMS team is daytime generally, and emergency-focused abdominal sonography for trauma (E-FAST) and vital sign can be checked during transport; airway

intubation and basic fluid therapy are also performed. However, surgical treatment, ventilator application, and extracorporeal membrane oxygenation (ECMO) are not allowed. In the case of a traumatic patient after HEMS transport, the trauma team is immediately called depending on the patient's vital signs and trauma history and in the trauma bay (trauma team activation). Accordingly, the specific treatment provided by trauma surgeons, cardiothoracic surgeons, neurosurgeons, and emergency medical specialists begins within 10 minutes.⁶⁾

The preventable trauma death (PTD) rate is conducted twice a month at our hospital and is conducted by a committee of 10 professional multidisciplinary panels, which consist of a general thoracic surgeon, cardiac surgeon, trauma surgeon, neurosurgeon, and emergency medical and orthopedics specialists in our hospital, which are reaffirmed by the panels of the Central Trauma Support Team during the quarterly evaluation of the RTC.

The criteria for the preventability of trauma deaths were based on the guideline of the World Health Organization for trauma quality improvement programs.¹⁹⁾ The main factors underlying the decision regarding the preventability of trauma deaths consisted of the severity of injuries and appropriateness of trauma treatment. The definitions are as follows: 1) "PTDs" are deaths, with accompanying injuries and sequelae considered survivable, that can definitely be prevented if an appropriate measure is taken. These cases exhibit straightforward deviations from the standard of care that directly or indirectly causes the patient's death. 2) "Potential or possible PTDs" are deaths with accompanying injuries and sequelae considered severe but survivable, that can potentially be prevented if an appropriate process is taken. These cases exhibit some deviations from the standard of care that directly or indirectly causes the patient's death. 3) "Non-PTDs" are deaths that are unavoidable due to the accompanying injuries and sequelae that are considered non-survivable, even with optimal treatment. Appropriate evaluation and management according to the accepted guidelines or standards are necessary. If the patient has co-morbid factors that are considered as major causes of death, such cases is considered as non-PTD. 4) "Non-preventable, but with care that could have been improved (NPCI)" is similar to non-PTDs; however care is questionable, or clear errors in care are detected, even though these do not lead to the death.

Statistical analysis

The difference of mortality and PTDR between HEMS group and non-HEMS group was analyzed statistically by the χ^2 test or Fisher's exact test (SPSS version 22.0; IBM Corp., Armonk, NY, USA). *p*-values of less than 0.05 were considered statistically significant.

RESULTS

Patient characteristics

The demographic characteristics of the 522 patients with overall doctor HEMS transport are summarized in **TABLE 1**. Of the 522 patients, 248 (47.5%) were trauma patients, whereas 274 (52.5%) were patients with diseases. We included 142 patients having neurosurgical diagnosis as main diagnosis including 94 patients with TBI and 48 patients with diseases. Especially in 142 neurosurgical cases, the mean age was 60 years, ranging from 3 to 93 years: 65% (92 of 142) of the patients were male. A total of 102 (72%) patients underwent emergency operation, and the mean flight time of the HEMS transport was 44 minutes, ranging from 27 to 64 minutes (**FIGURE 1**).

TABLE 1. Characteristics for overall patients using doctor HEMS transport

Variables	Trauma (n=248)	Disease (n=274)	Total (n=522)	p-value
Age (yr)	61 (2–99)	65 (1–97)	63 (1–99)	0.544
Female	54 (21.8)	113 (41.2)	167 (32.0)	0.045
CPR	12 (4.8)	9 (3.3)	21 (4.0)	0.075
Intubation	72 (29.0)	66 (24.1)	138 (26.4)	0.125
Neurosurgical patients	98 (39.5)	44 (16.1)	142 (27.2)	
Mean transfer time (min)	44 (27–74)	46 (31–78)	45 (27–78)	0.754
Operation	132 (53.2)	40 (14.6)	172 (33.0)	0.022
Procedure	15 (6.0)	135 (49.3)	150 (28.7)	0.010
At scene transfer	12 (4.8)	4 (1.5)	16 (3.1)	0.075
Mortality (3 months)	49 (19.8)	46 (16.8)	95 (18.2)	0.224

Values are presented as number of patients (%) or mean (range).

HEMS: helicopter emergency medical service, CPR: cardiopulmonary resuscitation.

Data of patients with TBI (grouping and preventable death rate data)

TBI patients using doctor HEMS were indicated in 98 patients (18.7%) among 522 overall HEMS patients. All patients with doctor HEMS transport have activated trauma team immediately after arriving the emergency or trauma room. The mean ISS of TBI patients was 32.3 and emergency surgery was performed in 78 patients (79.5%). The mean age of the study subjects were 61.7 years and male consisted 77.5% (76 of 98). The overall mortality was consisted in 21.4% (21 of 98) and 43.2% (42 of 98) was resulted in GOS 4 or 5 as good recovery. The PTDR of the HEMS group was significantly lower than that of the non-HEMS group (6.4% vs. 11.2%, $p=0.02$) The group of proper transport and treatment for severe TBI was consisted in 62.2% (61 of 98) including 13 mortality cases and no preventable death. The group of delayed transport or treatment for severe TBI was 18.3% (18 of 98) including 8 mortality cases and one preventable death (TABLE 2). The PTDR for TBI patients using the doctor HEMS was 4.8% including 1 patient of 21 mortality cases. The PTDR of TBI after the doctor HEMS transport was significantly lower than that of the overall TBI (4.8% vs.

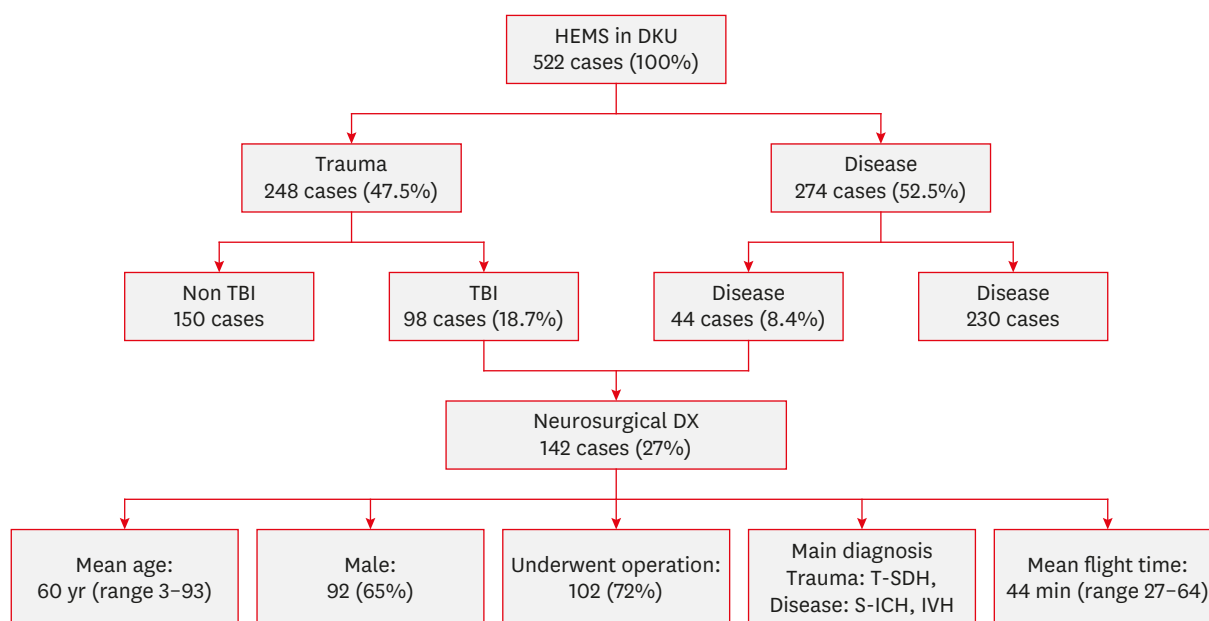


FIGURE 1. Characteristics of overall patients using doctor HEMS transport.

HEMS: helicopter emergency medical service, DKU: Dankook University, TBI: traumatic brain injury, DX: diagnosis, T-SDH: traumatic subdural hematoma, S-ICH: spontaneous intracranial hemorrhage, IVH: intraventricular hemorrhage.

TABLE 2. Characteristics for grouping of 98 TBI patients using doctor HEMS transport

Characteristics	Grouping			
	A (n=61)	B (n=18)	C (n=19)	Overall (n=98)
Sex				
Male	46 (75.4)	14 (77.8)	16 (84.2)	76 (77.6)
Female	15 (24.6)	4 (22.2)	3 (15.8)	22 (22.4)
Mean age	62 (7-84)	56 (7-84)	60 (3-83)	61 (3-84)
Initial mean GCS	6.5 (3-10)	7 (3-10)	13 (8-15)	(3-15)
Mean ISS	26.5	27.1	9.4	22.9
Head AIS				
5	35 (57.4)	10 (55.6)	0 (0)	45 (45.9)
4	26 (42.6)	8 (44.4)	0 (0)	34 (34.7)
3, 2	0 (0)	0 (0)	19 (100.0)	19 (19.4)
Treatment				
Surgery	54 (88.5)	16 (88.9)	4 (21.1)	74 (75.5)
Conservative	7 (11.5)	2 (11.1)	15 (78.9)	24 (24.5)
Outcome (at 6 months)				
GOS 1	13 (21.3)	8 (44.4)	0 (0)	21 (21.4)
GOS 2, 3	27 (44.3)	8 (44.4)	0 (0)	35 (35.7)
GOS 4, 5	21 (34.4)	2 (11.1)	19 (100.0)	42 (42.9)
Preventable death rate	0% (0 of 21)	4.8% (1 of 21)	0% (0 of 21)	4.8% (1 of 21)

Patients were divided into 3 groups as follows: group A: good transfer and treatment for severe TBI, group B: inadequate transfer or treatment for severe TBI, and group C: mild or moderate TBI. Values are presented as number of patients (%) or mean (range).

GCS: Glasgow Coma Scale, ISS: Injury Severity Scale, AIS: Abbreviated Injury Scale, GOS: Glasgow Outcome Scale.

TABLE 3. Statistical analysis of PTDR for total trauma patients from 2016 to 2017

PTDR variables	HEMS group (n=248)	None-HEMS group (n=4,864)	p-value
Mortality (%)	31 (12.5)	232 (4.8)	0.022
2016 years	17 (6.9)	125 (2.6)	
2017 years	14 (5.6)	107 (2.2)	
PTDR* (%)	2 (6.5)	26 (11.2)	0.042
Preventable	1 (3.2)	9 (3.9)	
Possible preventable	1 (3.2)	17 (7.3)	
None-preventable	22 (71.0)	159 (68.5)	
NPCI	7 (22.6)	47 (20.3)	
TBI subgroup PTDR (%)	4.8% (1 of 21)	11.7% (7 of 60)	0.045

HEMS: helicopter emergency medical service, NPCI: non-preventable, but with care that could have been improved, TBI: traumatic brain injury, PTDR: preventable trauma death rate.

*PTDR calculated with mortality as denominator.

11.6%, $p=0.045$) (**TABLE 3**). Moreover, the overall outcome of the doctor HEMS transport is demonstrated in **FIGURE 2**.

Case of potentially or possible preventable trauma death

A 65-year-old male presented to the hospital with headache and dizziness due to a motorcycle accident. The brain computed tomography (CT) revealed a small amount of subdural hematoma (SDH) at the right side of the frontotemporoparietal lobe. The patient was drowsy and did not exhibit full recovery after 2 hours. He asked to be transferred to our hospital by our doctor HEMS team due to hospital room shortage. The patient's blood pressure was high, and his mental state changed to stupor; in addition, his GCS score during the doctor HEMS transport was 9. Upon arrival at our hospital, brain CT was performed, which revealed increased SDH volume. However, a slight change in the state of consciousness and SDH volume was observed; thus, we transferred the patient to the trauma intensive care unit to closely observe the trauma progression. Subsequently, a brain CT scan was performed after 8 hours of hospitalization due to deterioration and fixation of right pupil reaction, and it revealed an increased SDH volume. Therefore, an emergency operation was performed; however, 7 days after the operation, the

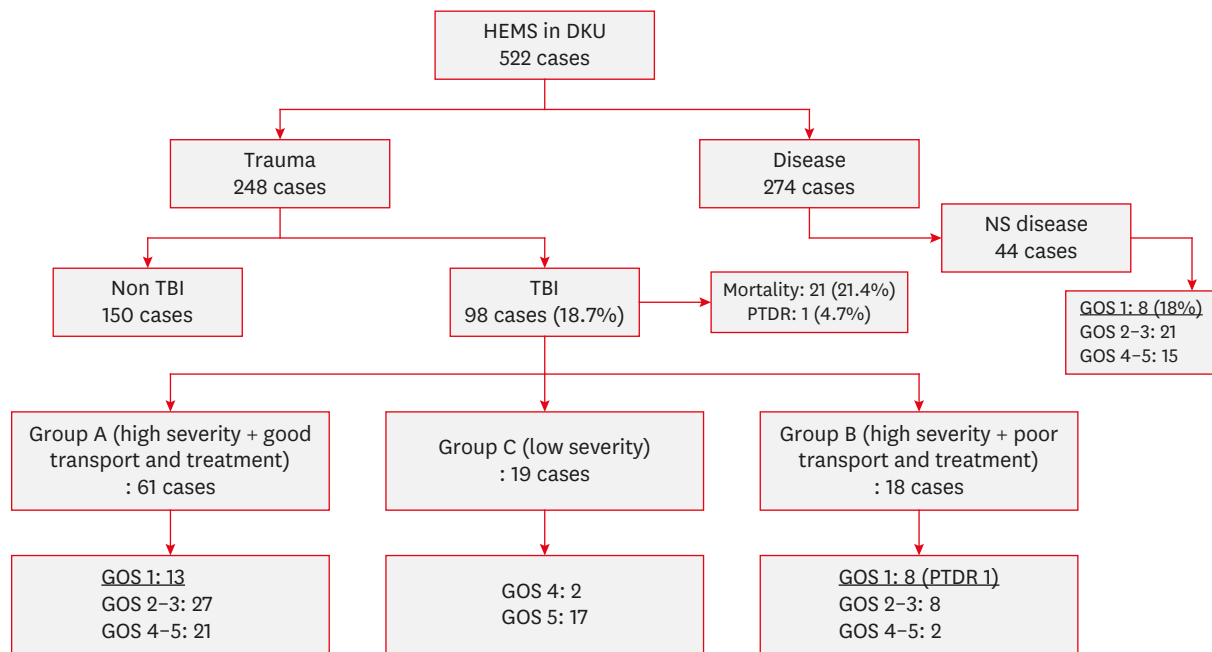


FIGURE 2. Outcome of TBI patients using doctor HEMS transport.

TBI: traumatic brain injury, HEMS: helicopter emergency medical service, DKU: Dankook University, NS: neurosurgical, GOS: Glasgow Outcome Scale, PTDR: preventable trauma death rate.

patient died due to severe brain edema with brain herniation. The patient was unconscious and did not exhibit recovery at the first hospital visit; however, he was not intubated despite the gradual decline in the GCS score, also was delayed hospitalization. Thus, it was concluded that there has been a transfer delay due to the long waiting time at the emergency room of the first hospital and the decision of surgical treatment was delayed after visiting the final hospital. The lack of an additional CT scan was also considered as a process error. Therefore, the committee decided to be a potentially or possible preventable trauma death, which had moderate severity of trauma and definite delay of transfer decision, operation and initial resuscitation.

DISCUSSION

The doctor HEMS transport system is known to have outstanding results in patient treatment, taking advantage of the transport speed and the benefits of the doctor's initial resuscitation, and is considered essential especially for severe trauma patients who need first aid immediately to the right hospital, at the right time. However, doctor HEMS in South Korea is implicated in most cases as a hospital-to-hospital transport and is rare in accident scene transport. This is due to the special situation in South Korea, which has relatively better in regional medical access and numerous helicopter flight restrictions.²⁰⁾

Patients with TBI are some of the most severely injured patients, in need of efficient, timely and more specialized care with generalized medical problems.⁴⁾ There are many diseases that require emergency transport and treatment, but among them, neurosurgery emergencies have the special characteristics of having the advantage of transferring the doctor HEMS transport. This is because most neurosurgical patients often arrive at the hospital with relatively stable vital signs such as blood pressure and respiration and heart rates, except

for cases with complicated neurological deficit, especially for cerebral hemorrhage, which requires more surgical treatment compared with other traumatic emergency conditions. Another reason is that there are relatively small volume of massive bleeding and multiple organ abnormalities, which results in more opportunities for definite treatments.

Appropriate HEMS transport resulted in a significant survival benefit compared with GEMS, despite the increased injury severity and incidence of posttraumatic complications including multiple organ dysfunction syndrome or sepsis.^{1,7)}

However, it is generally known that simply using these helicopters to quickly transport patients to hospitals cannot improve their overall prognosis. The outcome benefit dependent on the transportation mode seems to be influenced by several aspects, such as on-scene treatment, on-scene time and triage aspects that have to be discussed subsequently.^{5,13)} Appropriate transport followed by proper treatments is mandatory to achieve better outcome. The results of our study indicate that in most cases, good treatment practice, such as checking the patient's condition during transport and preparing or planning treatment in advance, through trauma team pre-activation during transport, improved the patient's prognosis. On the other hand, as in the case of preventable death patients, the delay in transfer and subsequent treatment were factors that adversely affected the patient's prognosis.

In a pooled analysis of all these studies by a Cochrane review, no benefit was found for helicopter transport in patients with TBI.⁸⁾ These studies, however, have limited generalizability, given their focus on single-center or regional analyses.⁸⁾ Aydin et al. described that the involvement of a physician-based helicopter emergency medical service (P-HEMS) increases on-scene times by 2.7 minutes without evident benefits for the overall patient outcome.³⁾ Interestingly, they observed a trend toward increased survival in the subgroup of P-HEMS treated patients with severe TBI.³⁾ Pakkanen et al.¹²⁾ reported positive results using HEMS that the introduction of a physician-staffed HEMS unit resulted in decreased incidence of prehospital hypoxia and increased the number of secured airways for severe TBI. This study include that the proportion of hypotensive patients on arrived to the emergency department was similar in both GEMS and HEMS group. However, the proportion of hypoxia was more higher in the patients managed by the paramedic GEMS without physician. Also, this study clearly demonstrates that older age was an independent risk factor for higher mortality and poor outcome in TBI as suggested in another studies.^{10,17)}

Our study has a similar conclusion to the above studies, securing airway for unconscious patients and preventing secondary brain damage through oxygen supply are known to affect very important treatment outcomes. In addition, we could indicate that rapid surgical treatment and changes in treatment plans due to changes in patient status during transport were other factors that made the patient's prognosis better. Until now, research papers for PTDR, which are limited to TBI, have been very rare. Especially, our paper may be first presentation those that have studied PTDR of TBI using doctor HEMS.

Prehospital trauma management is still a controversial issue with inconsistent evidence comparing the effects of helicopter and ground emergency transport on the results of severe trauma patients. In study from Andruszkow et al.,²⁾ the HEMS transport had a significant survival advantage compared to ground transport although high severity of trauma and high post-treatment complication including multiple organ dysfunction syndrome (MODS: acute kidney injury, pneumonia, hepatic failure, traumatic coagulopathy etc.) or severe sepsis.

They also proposed that the sensitivity and specificity of preclinical diagnoses in HEMS were not superior to those in GEMS and that the extent of preclinical treatment was more extensive in HEMS, thus resulting in prolonged on-scene times.

Recently, Jung et al.⁹⁾ stated that the PTDR in South Korea from January 1, 2015, to December 31, 2015 was 30.5%. Patients treated at a RTC exhibited a significantly lower PTDR than those who were not (21.9% vs. 33.9%; $p=0.002$). The PTDR was higher when patients were transferred from other hospitals than when they directly visited the final hospital (58.9% vs. 28.4%; $p=0.058$; borderline significant). Although a direct comparison is meaningless due to the differences in the study subjects, judgment of prevention possibilities, and statistical methods, the PTDR in South Korea has been consistently higher than those of some other industrialized countries. Recently, Motomura et al.¹¹⁾ reported that the PTDR in Chiba, Japan, is 29.0% in 2011. Moreover, Sanddal et al.¹⁴⁾ reported that the PTDR in Utah, USA is 6.7% in 2005, and Teixeira et al.¹⁸⁾ presented that the PTDR in California, USA, is 2.4% from 1998 to 2005. In summary, this study suggested that PTDR can be reduced if proper resuscitation and treatment are performed without delay after a proper triage of suspected severe trauma in a well-organized trauma center. Our analysis revealed that TBI accounts for the largest portion of a single disease entity among the diseases requiring doctor HEMS transport. In addition, a relatively high mortality rate and low PTDR, which evaluates the quality of treatment for trauma patients were observed.

There are some limitations in this study. First, it had a selective bias of dispatch which is transported in only daytime with good weather due to safety problem without nighttime transport. Second, also, the helicopter was transferred from the hospital to the hospital, not from the scene of the accident. Third, the grouping of patients with TBI was subjective or less accurate for reliability of treatment. Finally, evaluation of PTDR was self-assessed in our hospital committee. Therefore, further studies will be required to confirm more organized results of TBI patients using HEMS proved by well-designed and randomized, controlled another trial.

CONCLUSION

In patients with severe TBI, doctor HEMS can improve treatment outcomes by reducing surgical or medical treatment delay and unnecessary examinations. This result is proven by the fact that the PTDR of patients with TBI significantly decreases following the doctor HEMS transport. Especially, it is believed that the use of the doctor HEMS in severe TBI patients can prepare the treatment well and play a great role in the medical cooperation among the physician staff rather than the effect of shorten transfer time. The appropriate treatment is mandatory for real-time communication with the emergency doctor, as well as proper treatment preparation of the trauma team (trauma team pre-activation) during the HEMS transport.

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