Original article

Potential benefit of physician-staffed helicopter emergency medical service for regional trauma care system activation: An observational study in rural Japan

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Abstract

Objective: Involvement of all regional medical facilities in a trauma system is challenging in rural regions. We hypothesized that the physician-staffed helicopter emergency medical service potentially encouraged local facilities to participate in trauma systems by providing the transport of patients with trauma to those facilities in a rural setting.

Materials and Methods: We performed two retrospective observational studies. First, yearly changes in the numbers of patients with trauma and destination facilities were surveyed using records from the Miyazaki physician-staffed helicopter emergency medical service from April 2012 to March 2014. Second, we obtained data from medical records regarding the mechanism of injury, severity of injury, resuscitative interventions performed within 24 h after admission, secondary transports owing to undertriage by attending physicians, and deaths resulting from potentially preventable causes. Data from patients transported to the designated trauma center and those transported to non-designated trauma centers in Miyazaki were compared.

Results: In total, 524 patients were included. The number of patients transported to non-designated trauma centers and the number of non-designated trauma centers receiving patients increased after the second year. We surveyed 469 patient medical records (90%). There were 194 patients with major injuries (41%) and 104 patients with multiple injuries (22%), and 185 patients (39%) received resuscitative interventions. The designated trauma centers received many more patients with trauma (366 vs. 103), including many more patients with major injuries (47% vs. 21%, $p < 0.01$)

and multiple injuries (25% vs. 13%, $p < 0.01$), than the non-designated trauma centers. The number of patients with major injuries and patients who received resuscitative interventions increased for non-designated trauma centers after the second year. There were 9 secondary transports and 26 deaths. None of these secondary transports resulted from undertriage by staff physicians and none of these deaths resulted from potentially preventable causes.

Conclusion: The rural physician-staffed helicopter emergency medical service potentially encouraged non-designated trauma centers to participate in trauma systems while maintaining patient safety.

Key words: physician-staffed helicopter emergency medical service, field triage, rural trauma system

Introduction

Establishing a tiered trauma care system in a rural region involving local medical resources is challenging. Miyazaki prefecture, located in southwest Japan, is a rural region confronting this issue. In Miyazaki prefecture, there are approximately 1,110,000 residents within 6,700 km², with approximately 20 emergency physicians employed (1.8 emergency physicians per 100,000 people). Five years ago, there was no designated trauma center (DTC) in Miyazaki prefecture; however, there were some specialized hospitals or departments for specific illnesses, such as ischemic heart disease, stroke, and general surgery in the prefecture. The Trauma and Critical Care Center at the University of Miyazaki Hospital (UMH) was opened in 2012 as a center for critically ill patients with severe trauma, in particular, because patients with severe trauma always require a multidisciplinary approach. However, DTCs in Japan are not the same as a Level I trauma center in the US. DTCs in Japan are not only for patients with severe trauma but also for any critical patients. Thus, DTCs in Japan cannot always receive

all patients with trauma at any time, particularly those with minor trauma, because of limited resources (DTCs must focus on patients with severe trauma). For these reasons, in order to establish an effective trauma care system in Japan, it is necessary to establish a tiered trauma care system involving local facilities in rural regions, which in turn requires sophisticated prehospital triage.

In addition to its role as a trauma center, the UMH is also a base hospital for the Helicopter Emergency Medical Service (HEMS) in Miyazaki prefecture. In Japan, HEMS refers to a physician-staffed helicopter service (PS-HEMS)[1]. With this service, a HEMS physician reaches a patient at the landing point closest to the scene of the accident, performs optimal triage as well as minimal treatment, and determines the destination facility. Patients with severe injuries are always transported to the UMH (the only DTC in the region), and patients with minor or moderate injuries are sometimes transported to local non-DTCs. However, in Miyazaki prefecture, the time required for patient transportation may be very long, even with the use of a helicopter; therefore, in cases of undertriage, patients risk unfavorable outcomes. Thus, it is challenging for a rural PS-HEMS to establish a tiered trauma system without sacrificing patient safety.

In the present study, we hypothesized that a PS-HEMS encourages the local non-DTCs to treat patients with trauma by performing triage at the scene of accidents.

Materials and Methods

The PS-HEMS system in Miyazaki

The PS-HEMS is activated by fire stations and dispatched from the UMH, which is the base hospital of the PS-HEMS in Miyazaki prefecture. The criteria for PS-HEMS activation by fire station or emergency medical staff include any of the following situations: (i) when a patient is suspected to be critically injured or critically ill; (ii) when the patient's condition is severe and transport time is expected to be long; (iii) when the PS-HEMS would shorten the transport time for the injured patient (e.g., severe burn, multiple trauma, or amputation of extremities or fingers); or (iv) when a higher level of diagnosis or treatment than that provided by paramedics is needed. Service is requested by a telephone call to a dedicated line within the UMH. Since PS-HEMS flight is restricted to visible flight conditions, the PS-HEMS cannot dispatch during bad weather or at night. In the field, the HEMS physician performs a medical examination, administers treatment, and determines the destination facility. Specific rules, such as those in the Guidelines for Field Triage of Injured Patients[2], are not applied. From the scene, physicians ask the destination facility to receive the patient, and the patient is finally transported after agreement is obtained from the destination facility.

Decisions regarding secondary transport were made by physicians at the receiving hospital, when they were unable to treat the patient in their hospital.

Study method

This study is a retrospective observational study that contains data from two studies. One was conducted to assess changes in the regional trauma care system (study 1), and the other was conducted to assess whether the field triage was performed with appropriate maintenance of patient safety (study 2). In study 1, we identified the number of patients with trauma receiving care from the PS-HEMS from April 2012 to March 2015. We also identified their transport destination facilities from the PS-HEMS flight database (Figure 1). Transport destination facilities were categorized as follows: DTC, non-DTCs in Miyazaki prefecture, and facilities outside of Miyazaki prefecture. The UMH is the only DTC in Miyazaki prefecture, and non-DTC signifies a general hospital other than the UMH in Miyazaki prefecture.

In study 2, we excluded the following patients: patients whose exact data could not be obtained, patients who experienced cardiopulmonary arrest in the field, patients for whom the destination was already selected by paramedics, patients or transport facilities that did not provide consent to participate in this study, patients with incomplete medical records, and patients who were transported outside of Miyazaki prefecture. Finally, we enrolled the remaining 469 patients in the study (Figure 1).

Data were collected by visiting the facilities and reviewing the medical records. The mechanism of injury, severity of injury, and resuscitative interventions performed within 24 hours after admission were investigated and compared for patients who were transported to the DTC (DTC group) and those who were transported to local non-DTCs (non-DTC group).

Furthermore, secondary transport because of undertriage by HEMS physicians and in-hospital death resulting from potentially preventable causes[3-5] were assessed. These determinations were made by two co-authors (T.N. and H.O.) independently through discussion.

Definitions

The mechanism of injury was categorized as one of the following: traffic accident, fall, penetrating injury, laceration/incision/amputation outside of the trunk, and other blunt injury (e.g., tumbles, accidents involving industrial machines, sports-related accidents, crushing accidents, and accidents involving hitting a heavy structure). Injury severity was determined using the Revised Trauma Score
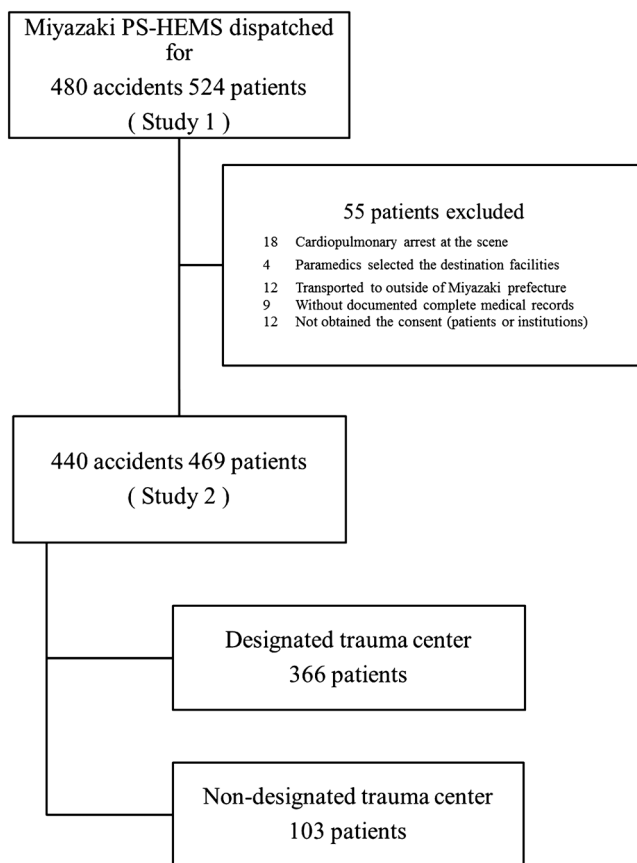
Figure 1 Flow diagram of the study. PS-HEMS, Physician-Staffed Helicopter Emergency Medical Service.

(RTS)[6], Abbreviated Injury Scale (AIS)[7], Injury Severity Score (ISS)[8], and probability of survival (PS). AIS and ISS scores were defined using the AIS98 updated criteria[9]. The RTS was calculated using the initial vital signs documented after HEMS physician arrival. PS was calculated using the Trauma and Injury Severity Score (TRISS)[10].

Major injury was defined as ISS > 15[11], and multiple injury was defined as AIS > 3 for 2 or more body parts. In this study, we defined resuscitative interventions within 24 hours after admission to the transport facilities as follows: surgery, interventional radiology, blood transfusion of 2 or more units, mechanical ventilation, and chest drain insertion. Secondary transport was defined as transportation from the initial admitting facility to a second facility for admission.

The definition of undertriage was "patients with severe injuries transported to lower-level trauma centers or other acute care facilities", as outlined in the resource guidelines published by the American College of Surgeons Committee on Trauma[12].

Ethical considerations

We explained the study details using an informed consent form provided to the local facilities that received patients transported by the PS-HEMS, and requested the medical records of the transported patients, including radiographs and information regarding diagnosis, interventions, and outcomes. We also requested that the facilities post the study disclosure and information on patients' rights and methods of refusal. Patients were determined to have agreed to participate in the study if they had not offered a refusal before October 16, 2015. Because this was an observational study, we were unable to obtain written consent from each individual. This study protocol was approved by the UMH Institutional Review Board (2015-108).

Statistical analysis

All non-parametric data were reported as medians and interquartile ranges (IQRs) and were assessed by the Mann-Whitney U test and chi-squared test to compare results between the DTC group and non-DTC group. Statistical significance was defined as $p < 0.05$. IBM SPSS (IBM SPSS Statistics, version 23, IBM Corp., Chicago, IL, USA) was used for all statistical analysis.

Results

Study 1 enrolled 524 patients, including 480 from the PS-HEMS operations. The number of overall patients increased to about 200 after the second year (Figure 2). Among them, 2 patients were not transported (data not shown); one patient died in the field, and the other patient was minimally injured. Transportation to facilities outside of Miyazaki prefecture decreased after the third year. Transportation to non-DTCs increased in number from the second year onward (first year vs. second year, 17 vs. 50, $p < 0.01$; first year vs. third year, 17 vs. 60, $p < 0.01$) (Figure 2). The number of non-DTCs that received patients with trauma also increased (Figure 3).

We excluded 55 patients from study 1 and included 469 patients, with 440 from PS-HEMS operations in study 2. The following patients were excluded: 18 patients who experienced cardiopulmonary arrest in the field, 4 patients who were already triaged by paramedics, 12 patients who were transported out of Miyazaki prefecture, 9 patients with incomplete documentation, and 12 patients who declined to participate in this investigation.

In study 2, the mean age was 53 years (IQR: 35–72 years), and the proportion of men was 69% (Table 1). The most frequent mechanism of injury was traffic-related injury (209 patients), followed by falls (139 patients), other blunt injuries (67 patients), lacerations/incisions/amputations out-
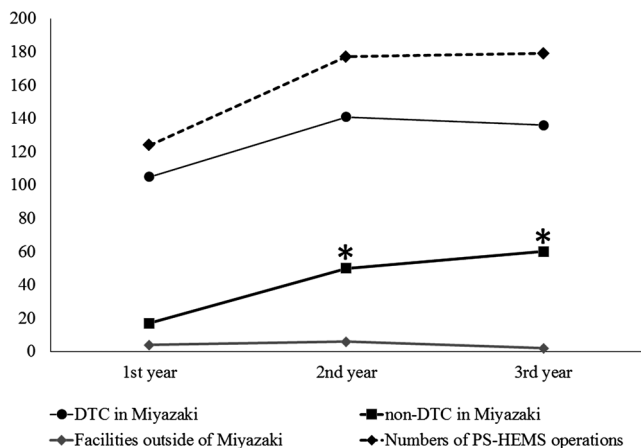
Figure 2 Numbers of PS-HEMS operations and patients. * Significant difference compared with number from the first year. PS-HEMS, Physician-Staffed Helicopter Emergency Medical Service; DTC, designated trauma center.

Figure 3 Numbers of facilities receiving patients with trauma.

side of the trunk (34 patients), burns (12 patients), and penetrating injuries (8 patients). The median RTS was 7.84 (IQR: 7.55–7.84), the median ISS was 10 (IQR: 4–25), and the median PS was 97.1% (IQR: 88.8–99.2%). There were 194 patients who experienced major injury (41%) and 104 patients with multiple injuries (22%). Within 24 hours of admission, 185 patients (39%) received resuscitative interventions. In total, 106 patients underwent surgery, 36 patients underwent interventional radiology, 80 patients received transfusions, 80 patients required mechanical ventilation, and 40 patients underwent chest drain insertion.

There were 9 secondary transports. Eight patients were transported from the DTC, and 1 patient was transported from a non-DTC to another non-DTC by ground ambulance. In the DTC group, 1 patient was transported by helicopter to a specialized center outside Miyazaki prefecture for admission to the pediatric intensive care unit, and the other 7 patients were transported by ground ambulance to local facilities within Miyazaki prefecture because these patients did not have major injuries or multiple trauma. The condition of the patient who underwent secondary transport from a non-DTC deteriorated after admission to the primary transport facility. No patients underwent secondary transport because of undertriage by the HEMS physicians. There were 26 in-hospital deaths (mortality rate: 5%), with 2 deaths in the non-DTC group (mortality rate: 2% in the non-DTC group). One patient died of severe head trauma, and the other patient, who was elderly, received no resuscitation attempts at his family's request. Thus, no deaths were determined to be owing to potentially preventable causes.

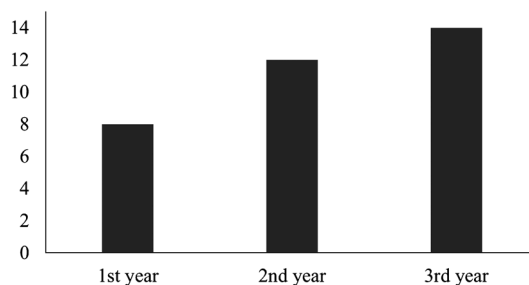Compared with non-DTCs, the DTC received a higher

Table 1 Descriptive baseline demographics

Demographics	N = 469
Age, median (IQR)	58, (35–72)
Male sex	323, (69)
Mechanism of injury	
Traffic-related injury	209, (45)
Burn	12, (3)
Fall	139, (30)
Penetrating	8, (2)
Laceration/Incision/Amputation	34, (7)
Other blunt injury	67, (14)
Injury severity	
RTS, median (IQR)	7.84, (7.55–7.84)
ISS, median (IQR)	10, (4–25)
PS, median (IQR)	97.1, (88.8–99.2)
PS < 50%	46, (10)
Major injury	194, (41)
Multiple injury	104, (22)
Resuscitative intervention within 24 h after admission	185, (39)
Surgery	106, (23)
IVR	36, (8)
Transfusion	80, (17)
Mechanical ventilation	80, (17)
Chest drain insertion	40, (9)
Resuscitative interventions for patients with major injuries	111, (57)
Secondary transport	9, (2)
In-hospital death	26, (6)
ISS > 15	25, (5)
ISS < 15	1, (0.2)
PS ≥ 50%	4, (1)
PS < 50%	22, (5)

Values are n, (%) unless indicated otherwise. IQR, interquartile range; RTS, Revised Trauma Score; ISS, Injury Severity Score; PS, probability of survival; IVR, interventional radiology.

number of patients (366 vs. 103; Table 2). The DTC received more patients with traffic-related injuries, as compared to non-DTCs (174 vs. 35, $p < 0.01$), while it received fewer pa-

Table 2 Descriptive comparison of patient demographics between groups

Demographics	Designated trauma center (n = 366)	Non-designated trauma center (n = 103)	p
Age, median (IQR)	58, (34–72)	60, (39–71)	0.58
Male	252, (69)	71, (69)	0.99
Mechanism of injury			
Traffic-related injury	174, (48)	35, (34)	< 0.01
Burn	9, (3)	3, (3)	0.73
Fall	114, (31)	25, (24)	0.18
Penetrating	6, (2)	2, (2)	0.69
Laceration/Incision/Amputation	12, (3)	22, (21)	< 0.01
Other blunt injury	51, (14)	16, (16)	0.68
Injury severity			
RTS, median (IQR)	7.84, (6.90–7.84)	7.84, (7.84–7.84)	< 0.01*
ISS, median (IQR)	13, (5–25)	6, (4–12)	< 0.01*
PS, median (IQR)	96.8, (87.7–99.1)	97.8, (96.8–99.4)	< 0.01*
PS < 50%	46, (13)	0, (0)	< 0.01
Major injury	172, (47)	22, (21)	< 0.01
Multiple injury	91, (25)	13, (13)	< 0.01
Resuscitative interventions within 24 h after admission	145, (40)	41, (40)	0.97
Surgery	69, (19)	37, (36)	< 0.01
IVR	32, (9)	4, (4)	0.1
Transfusion	66, (18)	14, (14)	0.29
Mechanical ventilation	75, (21)	5, (5)	< 0.01
Chest drain insertion	39, (11)	1, (1)	< 0.01
Resuscitative interventions for patients with major injuries	103, (60)	8, (36)	0.036
Secondary transport	8, (2)	1, (1)	0.691
In-hospital death	24, (7)	2, (2)	0.071
ISS > 15	24, (7)	1, (1)	0.319
ISS < 15	0, (0)	1, (1)	0.295
PS ≥ 50%	2, (0.5)	2, (2)	0.25
PS < 50%	22, (6)	0, (0)	n.a.

Values are n, (%) unless indicated otherwise. Chi-square test unless indicated otherwise. *Mann-Whitney U-test. IQR, interquartile range; RTS, Revised Trauma Score; ISS, Injury Severity Score; PS, probability of survival; IVR, interventional radiology; n.a., not applicable.

tients with lacerations/incisions/amputations outside of the trunk (12 vs. 22, $p < 0.01$).

The proportions of patients with major injuries (47% vs. 21%, $p < 0.01$) and multiple injuries (25% vs. 13%, $p < 0.01$) were higher in the DTC group. The ISS was higher in the DTC group than in the non-DTC group (13 [5–25] vs. 6 [4–12], $p < 0.01$). There were significant differences between the DTC group and non-DTC group in the values of RTS (7.84 [6.90–7.84] vs. 7.84 [7.84–7.84], $p < 0.01$) and PS (96.8% [87.7–99.1%] vs. 97.8% [96.8–99.4%], $p < 0.01$), based on Mann-Whitney U test results.

The proportions of patients who received all types of resuscitative interventions within 24 hours after admission were not different between the groups (40% vs. 39%, $p = 0.97$). In terms of individual interventions, mechanical ventilation (75 vs. 5, $p < 0.01$) and chest drain insertion (39 vs. 1, $p < 0.01$) were performed more frequently for patients in the DTC group, whereas surgery was performed more frequently for patients in the non-DTC group (69 vs. 37, $p < 0.01$). More resuscitative interventions were performed for patients with major injuries at the DTC than for those at non-DTCs (103 vs. 8, $p < 0.05$).

Regarding yearly changes, the number of patients with major injuries who were transported to both the DTC and non-DTCs increased after the second year. The number of patients with major injuries and the number of patients who received resuscitative interventions in the non-DTC group also increased after the second year (Table 3). In contrast, the number of the patients who did not have major injuries and did not receive resuscitative interventions increased in the DTC group, and their proportion remained close to 40% after the second year.

Table 3 Demographic changes per year

Demographics	1st year (n = 115)		2nd year (n = 177)		3rd year (n = 177)	
	DTC (n = 101)	non-DTC (n = 14)	DTC (n = 133)	non-DTC (n = 44)	DTC (n = 132)	non-DTC (n = 45)
Major injury	42, (42)	1, (7)	68, (51)	11, (25)	62, (47)	10, (22)
RI (+)	41, (41)	4, (29)	54, (41)	21, (48)	50, (38)	16, (36)
Non major injury + RI (−)	45, (45)	9, (64)	53, (40)	16, (36)	54, (41)	23, (51)
Non major injury + RI (+)	14, (14)	4, (29)	12, (9)	17, (39)	16, (12)	12, (27)
Major injury + RI (−)	15, (15)	1, (7)	26, (20)	7, (16)	28, (21)	6, (13)
Major injury + RI (+)	27, (27)	0, (0)	42, (32)	4, (9)	34, (26)	4, (9)

Values are n, (%). DTC, designated trauma center; ISS, Injury Severity Score; RI, resuscitative interventions.

Discussion

Our studies showed that the number of patients transported to non-DTCs had increased, and the number of non-DTCs receiving patients had also increased, without secondary transport because of undertriage or death resulting from potentially preventable causes. These findings suggest that the PS-HEMS potentially encouraged the local non-DTCs to treat selected patients with trauma.

In order to save large numbers of patients with trauma, the establishment of a regional trauma care system is necessary. Several studies have reported the effectiveness of organized trauma care systems[13–15]. In Japan, an emergency medical services system was established in 1977[16]. The system comprised tiered facilities that were assigned to one of three categories based on their capabilities to provide emergency medical care. These categories are not only for patients with trauma specifically, but also for any emergency patients in Japan. The PS-HEMS was established in 2001 in some areas, and gradually spread to many regions in Japan[1]. In Miyazaki prefecture, there are 1.8 emergency physicians per 100,000 citizens, although there are 6.8 emergency physicians per 100,000 citizens in Iowa, the state with the lowest ratio in the US[17]. The UMH is the only DTC as well as the only base hospital for physician-staffed helicopters in the prefecture.

The factors described above might have influenced triage in the field in the first year of the Miyazaki PS-HEMS because the HEMS physicians triaged 88% of patients to the DTC, although 45% of the patients without major injuries and received no resuscitative interventions. Of the 12% of patients triaged to non-DTCs during this time, only 1 patient with major injury; however, the patient received no resuscitative interventions. This distribution pattern was inappropriate. For this reason, transport to non-DTCs increased after the second year of the PS-HEMS. Interestingly, the group of patients that received transport to non-DTCs included about 24% (6% of all patients) of patients with major injuries; however, these patients experienced no deaths resulting from potentially preventable causes.

This increase in transport to non-DTCs raised concerns of undertriage. The acceptable rate of undertriage changes on the basis of the definition of undertriage. According to the American College of Surgeons Committee on Trauma resource guidelines[12], if major trauma is defined by an ISS score > 15, the acceptable undertriage rate is defined as the percentage of patients transported to non-DTCs whose ISS scores are > 15; the rate should be less than 5%. Another definition of acceptable undertriage rate is the percentage of patients who die from potentially preventable causes among patients transported to non-DTC; the rate should be less than 1%. In the present study, 6% of patients with ISS scores > 15 were transported to non-DTCs after the second year; however, no deaths from potentially preventable causes were observed. Thus, our field triage by the PS-HEMS was acceptable with respect to undertriage. Furthermore, no patient had a PS below 50%, and 58% of patients did not receive resuscitative interventions in the non-DTC group after the second year. Therefore, we concluded that the PS-HEMS triage maintained patient safety. Finally, we concluded that the PS-HEMS encouraged local non-designated trauma facilities to participate in the trauma care system while maintaining patient safety through the transport of selected patients with trauma to these facilities.

In contrast, overtriage may remain a problem. In the second and third years, 49% and 53% of patients did not have major injuries, and 59% and 62% of patients did not receive resuscitative interventions in the DTC group, respectively. According to the American College of Surgeons Committee on Trauma resource guidelines, an overtriage rate from 25% to 35% is acceptable[12]. A recent opinion suggests that 7–15% of patients with trauma must be treated at the highest level of trauma center[18]. This is unfavorable with respect to optimal destination, regionalization of the trauma system, and cost[19]. However, field overtriage standards in the setting of mature trauma systems may not apply to field triage in ru-

ral immature trauma systems such as Miyazaki prefecture, because there are few DTCs. The overtriage rate might reflect the degree of rurality and effort to prevent undertriage.

Even in a rural setting, it is necessary to recruit non-designated trauma facilities and non-trauma physicians and surgeons to the trauma care system in order to provide adequate trauma care. Utter *et al.* reported that mortality of patients with severe trauma improved in inclusive systems compared with that in exclusive systems[20]. Furthermore, trauma care systems should also be established for potential mass casualty incidents. For example, after the Boston Marathon bombing in 2013, 26 facilities received patients[21]. After the 2015 terror attack in Paris, 16 facilities received emergency patients[22]. Although these incidents occurred in urban settings, several facilities received patients with severe trauma and provided trauma care in both mass casualty incidents. Thus, not only DTCs but also local facilities in the area should be included in the trauma care system, which should be tiered based on facility capabilities to treat patients according to injury severity. Our PS-HEMS sometimes transported patients with major injuries who required resuscitative interventions even to the local non-designated trauma facilities, and this might be needed to enhance the rural trauma care system.

The present study was limited by its inclusion of only patients who were injured in weather conditions conducive to helicopter flights in the daytime, and by a short study period. The distribution of patients with trauma before the introduction of the PS-HEMS was not examined. Thus, we cannot conclude whether the regional trauma systems became truly regionalized. Therefore, further observational studies, including those of transport by EMS only in the entire region, are needed to describe regional trauma system changes. Further investigation is also needed to determine the long-term outcomes for the patients in this study.

Conclusion

In this observational study, the PS-HEMS was found to potentially have a role in encouraging the local non-designated trauma facilities to participate in the regional trauma care system by transporting selected patients to those facilities. Triage by HEMS physicians was determined to be safe and accurate for patients with trauma because there were no instances of undertriage or death owing to potentially preventable causes. The rural PS-HEMS potentially has a role in the establishment of an effective regional trauma care system.

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