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Original Research

Comparison of Changes in Vital Signs During Ground and Helicopter Emergency Medical Services and Hospital Interventions

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A B S T R A C T

Objective: Few studies have evaluated the effects of helicopter emergency medical services (HEMS) alone. This single-center study compared the changes in vital signs during ground emergency medical services (GEMS), HEMS, and hospital interventions to assess the impact of HEMS interventions.

Methods: This retrospective observational study included 168 trauma patients older than 18 years of age who received HEMS. Patients with cardiac arrest or those who received medical attention before HEMS were excluded. We assessed 3 intervention phases (GEMS, HEMS, and hospital). The changes in heart rate, systolic blood pressure, respiratory rate, and shock index in response to interventions were calculated and divided by the intervention time, and the changes observed during the interventions were compared.

Results: No changes in vital signs were observed when receiving GEMS. Systolic blood pressure increased and shock index decreased after HEMS, whereas systolic blood pressure decreased and shock index increased during hospital interventions. Heart rate showed no significant change (P = .12), and respiratory rate showed very little change. Systolic blood pressure increased significantly during HEMS compared with the pre- and postintervention periods.

Conclusion: Changes in vital signs differed according to the intervention. Systolic blood pressure increased during HEMS but not with GEMS or hospital interventions.

Helicopter emergency medical services (HEMS) are becoming increasingly popular for the rapid dispatch of trained emergency medical teams to prehospital areas. The primary objective of HEMS is to provide early medical intervention to patients and transport them quickly to the appropriate medical institution, ultimately improving their prognosis.[1-3] The effectiveness of HEMS has been investigated because their operating cost and the risk of operational accidents are higher than those with ground emergency medical services (GEMS).[1-3] In these reports, the primary end point was patient prognosis, and HEMS were preferable to GEMS. However, because patients receive a series of interventions from GEMS, HEMS, and the hospital, there is a strong presumption that patient prognosis reflects the overall impact of this series of interventions. Therefore, a comparison of the outcomes of patients transported by HEMS with those of patients transported by GEMS cannot help in the assessment of the direct effects of HEMS interventions on the condition of patients, and the effects of HEMS interventions on changes in patient conditions remain unclear. To investigate the direct effects of HEMS interventions, it is necessary to compare the changes in patient conditions caused by the HEMS interventions with those caused by other interventions. We hypothesized that different interventions may be associated with different changes in patients' conditions. In this study, we aimed to identify the changes in patient status due to HEMS interventions by evaluating the changes in vital signs during GEMS, HEMS, and hospital interventions.

Methods

Study Design

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards. This

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retrospective observational study was approved by the Research Ethics Committee of Nara Medical University, Kashihara City, Nara, Japan (approval number: 2362). The need for informed consent was waived because of the retrospective observational nature of the study. Data were obtained from the prospectively collected medical records of the HEMS at our institution and the electronic medical records of the Nara Medical University hospital.

Study Patients

Because this was an exploratory study, we were not able to establish the required sample size. The observation period of the study was 3 years, from March 2017 to June 2020. The inclusion criteria were trauma patients older than 18 years of age who were transported from accident sites to the Nara Medical University hospital and treated with medical interventions by helicopter staff. The exclusion criteria were patients who 1) received cardiopulmonary resuscitation, 2) were treated by other physicians at the scene before any interventions by the emergency team, 3) were not transported by helicopter, and 4) had missing data.

Overview of Each Intervention Operation in the Study Region

Operation of GEMS

GEMS are dispatched after an emergency call. In ordinary situations, the response rate is 100%. GEMS in Nara Prefecture is composed of 4 or 5 paramedics. When a patient is transferred to HEMS, GEMS promptly transports the patient with minimal treatment to avoid worsening the patient's condition. HEMS can be requested directly from the GEMS if it is suspected that there will be a delay in rescuing or transporting the patient. GEMS interventions will continue until the HEMS takeover.

Operation of HEMS

HEMS operated in the Nara Prefecture are activated by an emergency call. Generally, the HEMS crew of Nara consists of 1 pilot, 1 mechanic, 1 emergency physician, and 1 nurse. When a patient is assessed as critically ill, according to the information in the emergency call, the emergency call center (ECC) requests the HEMS to mobilize at the same time as the GEMS. Even if the ECC does not request HEMS initially, if the GEMS considers that HEMS is necessary based on their observation of the patient, HEMS is requested through the ECC. The patient is transported by the GEMS to the landing point for contact with the HEMS while undergoing procedural intervention by the GEMS. The helicopter with a doctor and nurse from the base hospital assumes care of the patients delivered to them by the GEMS at the landing point near the accident site. If time is needed for a rescue operation (eg, rescue from a trapped car), the HEMS takes over from the GEMS on-site and provides intervention. HEMS interventions continue until arrival at the medical facility and responsibility is handed over to the hospital staff. After arriving at the medical institution, patients are immediately taken to the emergency department and interventions continue.

Medical Treatment System in the Hospital

In the hospital, a team of 4 or more doctors, nurses, and paramedics will take over treating the patients from the HEMS. Trauma surgeons, orthopedic surgeons, and neurosurgeons are always ready to perform immediate surgery in the emergency room if necessary. If a patient's condition is stable, the patient may be transported to the emergency room after imaging studies are performed in the adjacent computed tomographic imaging room.

Main Activities Performed During Each Intervention

For GEMS, significantly limited procedures are available for patients with noncardiac arrest. The main activities include securing venous access and administering lactated Ringer solution for noncardiac shock and compartment syndrome, administering oxygen, securing the airway using manual and instrumental techniques, and performing hemostasis with compression and hemostatic devices.

In addition to the interventions provided by the GEMS, emergency procedures performed by HEMS include using medical devices (massive infusion, intubation, surgical airway management, mechanical ventilation, defibrillation, transcutaneous pacing, thoracostomy, ultrasound examination, and hemostasis using a tourniquet or abbreviated surgery), drug administration (eg, painkillers, antiemetics, tranexamic acid, sedative drugs, muscle relaxants, and antihypertensive drugs), and assessment with ultrasonography and electrocardiography.

In addition to the HEMS interventions, procedures performed in the hospital include performing rapid imaging, blood tests, blood transfusions, emergency surgery (head, trunk, pelvis, extremities, spine, and amputated limb), and interventional radiology (IVR) (emergency surgery and IVR can be initiated within 30 minutes).

Measuring and Recording Vital Signs

During GEMS interventions, vital signs (heart rate [HR], systolic blood pressure [SBP], diastolic blood pressure, and respiratory rate [RR]) are measured as soon as possible after contact with the patient. They are recorded manually, usually every 5 minutes, using an automatic measuring device installed in each ambulance. Vital signs during HEMS interventions are measured using automatic measuring instruments (X Series Monitor/Defibrillator; Zoll Medical Corp, Chelmsford, MA) and recorded manually. Vital signs in the hospital are recorded automatically on electronic media (IntelliVue MX800; Philips, Amsterdam, Netherlands).

Data Collection

The collected data were age, sex, medicine (beta-blockers/antithrombotic therapy), trauma mechanism, trauma severity, transport methods, necessity of hemostatic treatment (hemostatic surgery/IVR), and 28-day mortality. Four vital sign measurements (HR, SBP, RR, and shock index [SI] = HR/SBP) were collected before and after each intervention phase (GEMS, HEMS, and hospital). Each intervention phase was defined as follows: the GEMS phase was from the arrival of the GEMS to the arrival of the HEMS, the HEMS phase was from the arrival of the HEMS to arrival at the hospital, and the hospital phase was from arrival at the hospital to the first measurement 30 minutes after arrival.

Statistical Analyses

First, we compared the vital signs and intervention times between each intervention. Next, we compared the differences in vital signs. However, the variability of vital signs has been reported to increase with the length of the intervention.[4,5] Therefore, for each vital sign, we calculated the differences between the values before and after the intervention and divided by each intervention time (hour) and compared the overall tendencies to examine the relationship with the intervention. Because of skewness in each measurement, the Wilcoxon signed rank test was used to compare 2 related samples, and the Friedman test was used to compare 3 or more related samples. To adjust for multiple comparisons, we used the post hoc Wilcoxon signed rank test and the Friedman test with an applied Bonferroni correction. Continuous variables are described as median and interquartile ranges, and categoric variables are described as numbers and percentages. A P value < .05 was considered statistically significant. Data analysis was performed using R version 3.6.3 (R Development Core Team, Vienna, Austria).

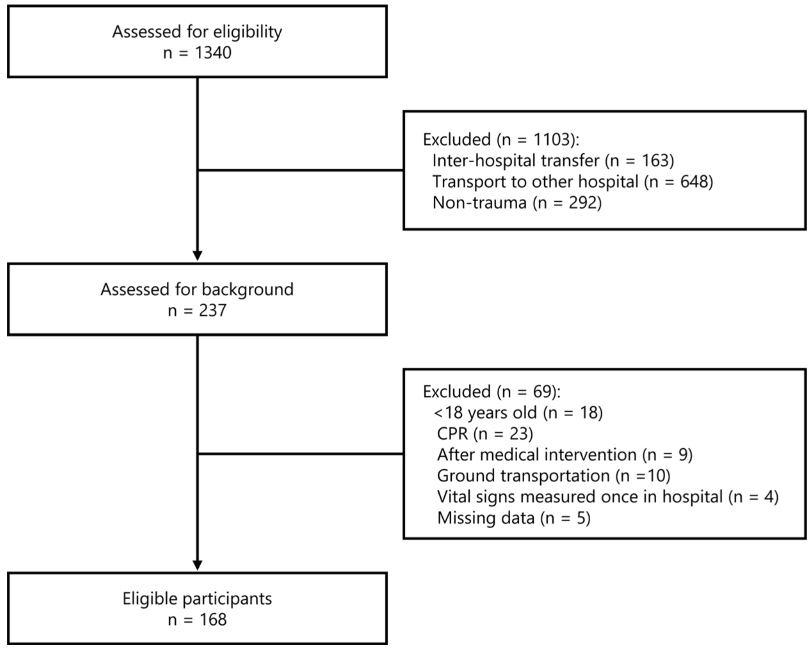

Figure 1. The study flowchart. CPR, cardiopulmonary resuscitation.

Results

During the observation period, 1,340 patients received medical interventions via the Nara HEMS, and 237 trauma patients were transported from the accident site to our hospital. Of these, 168 were included in this study (Fig. 1). The median age of the study patients was 63 years, and 77.4% were men. A total of 160 patients (95.2%) had blunt trauma, and the median Injury Severity Score was 10. Patients with an Injury Severity Score ≥ 16, which was defined as severe, comprised 35.8% (n = 58) of the total study population. After arriving at a medical institution, emergency hemostasis surgery was performed in 53 (32.7%) patients and IVR in 7 (4.3%) patients. The 28-day mortality rate was 6.8% (Table 1).

Table 1
Patient Details

Variables	Study Patients (N = 168)	
Patient demographics		
Age (y), median (IQR)	63	(48-73)
Sex (male), n (%)	130	(77.4)
Medication history, n (%)		
Antithrombotic therapy	14	(8.3)
Beta−blocker	2	(1.2)
Mechanism of injury, n (%)		
Blunt injury	160	(95.2)
Motor vehicle crashes	74	(44.0)
Fall	49	(29.2)
Crush	17	(10.1)
Tumble	11	(6.5)
Amputation	5	(3.0)
Other blunt trauma	4	(2.4)
Penetrating injury	8	(4.8)
Injury data		
ISS, median (IQR)	10	(5-20)
ISS ≥ 6, n (%)	58	(35.8)
Urgent treatment in hospital, n (%)		
Surgery	53	(32.7)
Interventional radiology	7	(4.3)
Outcome, n (%)		
Mortality (28-day)	11	(6.8)

IQR = interquartile range; ISS = Injury Severity Score.

Table 2 lists the interventions performed for each intervention phase. The following were the most frequently performed interventions for each intervention phase: GEMS, oxygen administration; HEMS, fluid infusion, painkiller administration, and ultrasound examination; and in the hospital, imaging examinations (X-ray/computed tomographic imaging) and blood tests performed within the first 30 minutes of arrival at the hospital. From arrival at the hospital to the first vital sign measurement, no patient underwent hemostatic surgery or IVR.

Table 3 shows the vital sign measurements before and after each intervention and a comparison of the duration of each intervention. There was no significant change in HR. However, significant changes in SBP and SI were observed. SBP increased significantly between contact with the HEMS and arrival at the hospital. The SI was significantly different overall, with the lowest values being observed during HEMS interventions. Although there were significant differences in the overall RR, no significant changes were observed.

Next, we evaluated the changes in vital signs after each intervention (Fig. 2). The change in HR per intervention time was significantly higher during HEMS intervention than during GEMS intervention. The change in SBP increased with HEMS intervention but decreased with hospital intervention. The change in SI increased during hospital intervention. The change in RR was not significantly different throughout the intervention phase.

Discussion

In this study, to evaluate the effects of HEMS interventions, changes in vital signs before and after HEMS interventions were compared with those in other pre- and postinterventions. Changes in vital signs varied according to different parameters; SBP increased significantly during HEMS interventions, and SI worsened during post-HEMS (hospital) interventions. To our knowledge, this is the first study to compare the effects of consecutive interventions on vital signs.

Regarding prehospital activities, appropriate interventions have been shown to contribute to better outcomes than early transport.[6-10] However, the sequence of interventions applied to patients in the prehospital phase has different limitations. Therefore, evaluating the effects of each intervention on a patient's condition is important when considering which interventions should be prioritized. The

Table 2
Interventions Performed in Each Phase

Intervention	Intervention Phase (N = 168)		
	GEMS n (%)	HEMS n (%)	Hospital n (%)
Airway			
Intubation	0 (0.0)	15 (8.9)	15 (8.9)
BVM ventilation	7 (4.2)	15 (8,9)	0 (0.0)
Breathing			
Oxygenation	102 (60.7)	89 (53.0)	89 (53.0)[a]
Chest tube	—	1 (0.6)	5 (3.0)
Circulation			
Fluid infusion	3 (1.8)	168 (100.0)	168 (100.0)[a]
Splint	0 (0.0)	8 (4.8)	3 (1.8)
Compression, tourniquet	1 (0.6)	1 (0.6)	2 (1.2)
Primary hemostasis	0 (0.0)	11 (6.5)	0 (0.0)
Surgical intervention	—	—	8 (4.8)
Transfusion	—	—	3 (1.8)
CNS dysfunction			
Sedation	—	4 (2.4)	29 (17.3)
Drug			
Painkiller	—	61 (36.3)	52 (31.0)
Antiemetic	—	41 (24.4)	6 (3.6)
Tranexamic acid	—	4 (2.4)	19 (11.3)
Sedative drug	—	4 (2.4)	29 (17.3)
Muscle relaxants	—	9 (5.4)	13 (7.7)
Antihypertensive agent	—	6 (3.6)	9 (5.4)
Vasopressor agent	—	2 (1.2)	3 (1.8)
Imaging examination			
FAST	—	137 (81.5)	93 (55.4)
CT imaging	—	—	147 (87.5)
X-ray	—	—	132 (78.6)
MRI	—	—	2 (1.2)
ECG	—	—	49 (29.2)
Laboratory examination			
Blood test	—	—	166 (98.8)

[a] Indicates that the intervention was continued.BVM = bag valve mask; CNS = central nervous system; CT = computed tomographic; ECG = electrocardiogram; FAST = focused assessment with sonography for trauma; GEMS = ground emergency medical services; HEMS = helicopter emergency medical services; MRI = magnetic resonance imaging.

Table 3
Comparison of Vital Signs Before and After Each Intervention and Treatment Duration

Variables	GEMS Arrival	HEMS Arrival	Hospital Arrival	Approximately 30 Minutes After Arrival	*P* Value
HR (beats/min)[a]	84 (68-100)	80 (70-94)	80 (70-95)	83 (72-97)	.12
SBP (mm Hg)[a]	135 (116-154)	133 (116-156)	145 (124-161)	142 (127-159)	<.001
SI (beats/min • mm Hg)[a]	0.61 (0.51-0.73)	0.59 (0.50-0.70)	0.55 (0.47-0.67)	0.58 (0.48-0.71)	<.001
RR (beats/min)[a]	20 (18-24)	20 (18-24)	20 (16-23)	18 (15-21)	<.001
Treatment time (min)[a]	GEMS phase 26 (20-35)	HEMS phase 40 (32-50)	Hospital phase 32 (30-35)		<.001

[a] Median (interquartile range).GEMS = ground emergency medical services; HEMS = helicopter emergency medical services; HR = heart rate; RR = respiratory rate; SBP = systolic blood pressure; SI = shock index.

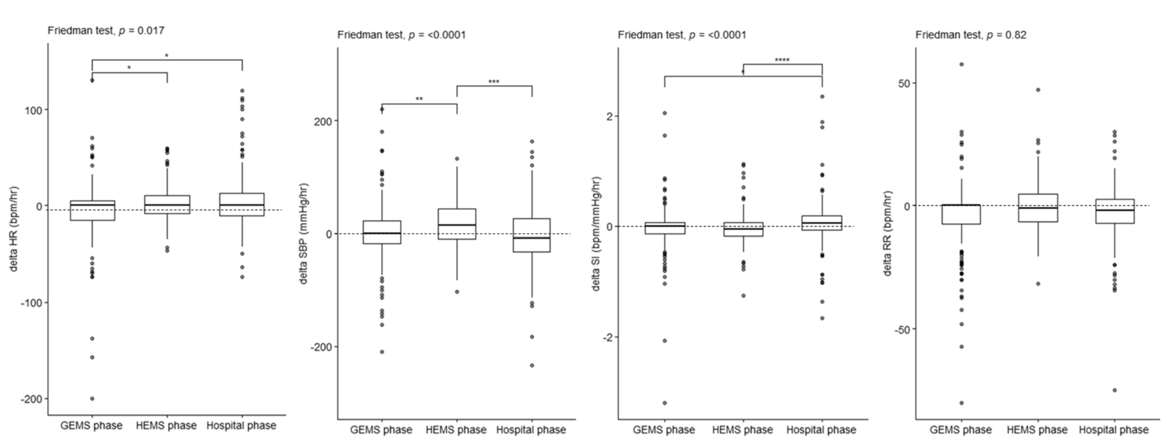

Figure 2. A comparison of changes in vital signs with each intervention.

interventions in this study had increasing limitations in the order of GEMS > HEMS > hospital, and there were inevitable limits as to what could be performed during each intervention. We considered that the SBP increase observed during HEMS interventions offered a rationale for prioritizing a shift in interventions from the GEMS to the HEMS in patients who needed it.

Several reports have pointed to patient characteristics in studies on the prognostic effect of physician helicopters. The patient backgrounds in which HEMS interventions were more effective were those with a high severity and poor condition.[3,10-13] The SBP increase observed during HEMS interventions in this study may have had a favorable effect on patients in poor condition, suggesting that it may have contributed to the improved prognostic effect of the HEMS.

This study has several limitations. First, this was a single-center, retrospective study conducted in a small area. Therefore, the results of this study need to be validated in other locations because different countries and regions may have different intervention protocols and health care systems. However, the comparison between the different interventions used in this study may be a useful way to examine the effects of interventions on vital signs.[14] Second, vital signs alone were not sufficient to identify those patients who required early medical intervention. However, vital signs remain an important parameter for assessing patients' conditions in clinical practice. In particular, changes in vital signs occurring in the early stages of intervention have been reported to be associated with prognosis.[3-5] Therefore, although the present study focused on changes in vital signs, more accurate prognostic parameters should be used. Third, we could not evaluate other changes in vital signs beyond the effects of the interventions presented in patients' medical records. The vital signs of critically ill and injured patients may change during a short time period,[15-17] which was not taken into consideration in this study. However, the transient increase in SBP during HEMS interventions was significantly relative to the pre- and postintervention values, and this change cannot be explained by the natural history of the patient alone. Finally, there may have been insufficient interventions by the GEMS and the hospital. The GEMS may have prioritized transferring patients to the HEMS, which may have minimized intervention. In addition, the intervention time in the hospital was limited to the first 30 minutes and, therefore, mainly consisted of imaging assessments rather than interventions. Therefore, each intervention may have been underestimated; however, this could not be examined because of the retrospective nature of the study.

HEMS interventions were associated with a predominant increase in SBP relative to that with GEMS and hospital interventions. A comparison of the effects of each intervention on vital signs may provide useful information for determining the quality and preferred duration of interventions.

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