Original report

A comparison between evacuation from the scene and interhospital transportation using helicopter for subarachnoid hemorrhage

Running head: SAH evacuated by Dr. Heli

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Abstract

Purpose: We investigated the changes in the vital signs and the final outcomes subarachnoid hemorrhage (SAH) patients who were evacuated from the scene using the doctor-helicopter (Dr. Heli) service and those who only underwent interhospital transportation using the doctor-helicopter Dr. Heli service to investigate safety of this system

Methods: We retrospectively investigated all of the patients with non-traumatic SAH who were transported by a Dr. Heli between January 2010 and March 2016. The subjects were divided into two groups: the Scene group included subjects who were evacuated from the scene by a Dr. Heli, while the Interhospital group included subjects who were transported by a ground ambulance to a nearby medical facility and then transported by a Dr. Heli to a single tertiary center.

Results: The systolic blood pressure, ratio of cardiac arrest, and Fisher classification values of the patients in the Scene group were significantly greater than those in the

Interhospital group. The Glasgow Coma Scale in the Scene group was significantly lower than that in the Interhospital group. After excluding the patients with cardiac arrest, the Glasgow Coma Scale scores of the patients in the two groups did not differ to a statistically significant extent during, before or after transportation. There were no significant differences in Glasgow Outcome Scores or the survival ratio of the two groups, even when cardiac arrest patients were included.

Conclusion: The present study indirectly suggests the safety of using a Dr. Heli to evacuate SAH patients from the scene.

1. Introduction

Previous studies have reported the survival benefits of air ambulances in the evacuation of trauma patients from the scene. [1-5] However, there have been few reports on the usefulness of air ambulances in the inter-hospital transportation of non-trauma patients, especially those with acute coronary syndrome or stroke, in which time-dependent management is required in order to obtain a favorable outcome. [6-11] In the case of stroke, recent reports have focused on ischemic stroke patients who were candidates for tissue plasminogen activator infusion. [7,8] We herein report the results of a retrospective analysis to investigate the change in patients' vital signs during transportation and the outcomes of evacuating subarachnoid hemorrhage (SAH) patients from the scene using a government-funded medical helicopter service known as "doctor-helicopter" (Dr. Heli). The purpose of the current study was to determine whether SAH patients could be safely transported from the scene based on their clinical condition during transport and their outcomes.

2. Methods

The protocol of this retrospective study was approved by our institutional review board, and the examinations were conducted according to the standards of good

clinical practice and the Helsinki Declaration.

We retrospectively investigated all of the patients with non-traumatic SAH who were transported by a Dr. Heli between January 2010 and March 2016, during which time hospital medical charts were preserved according to Japanese law, using the registry data of the Dr. Heli control room of our hospital. We did not include the SAH patients who were transported to our hospital directly, either by self-transport or ground ambulance. The exclusion criteria were as follows: 1) patients with trauma; 2) patients who did not use a ground ambulance; 3) patients who were delivered to other medical facilities; 4) cases in which SAH was ruled out based on the results of a computed tomography (CT) examination that was performed after arrival at our hospital. The diagnosis of SAH was determined by CT. In our institute, patients with sudden-onset headache without visible SAH on the CT undergo magnetic resonance imaging (fluid-attenuated inversion recovery) and magnetic resonance angiography, or CT angiography.

The subjects were divided into two groups: the Scene group included subjects who were evacuated from the scene by a Dr. Heli, while the Interhospital group included subjects who were transported to a nearby medical facility by a ground ambulance and then transported to our hospital by a Dr. Heli after the diagnosis of SAH.

The primary outcome measures were safety during air-transportation, including changes of vital signs, which were examined in order to investigate the safety of the Dr Heli system. The secondary outcome measure was the final outcome in terms of the Glasgow Outcome Score at discharge and the survival rate in the patients of the two groups. The subjects in the Scene group were diagnosed by CT after arrival at our hospital. The decision to access Dr. Heli on scene was made by emergency medical technicians, based on the subjects' complaints or symptoms, such as severe headache with sudden onset, unconsciousness or hemiparesis. The patients' age, sex, Glasgow Coma Scale, systolic blood pressure, heart rate (at first contact, when it was checked by the Dr. Heli staff), presence/absence of cardiac arrest, percentage of tracheal intubation, Fisher scale, Glasgow Outcome Score at discharge and the survival rate were investigated in the two groups. [12] In the Scene group, the reason for calling for a Dr. Heli was investigated. In addition, we performed a further analysis of the two groups after excluding subjects with cardiac arrest. Concerning the analyses, the proportions of patients using anti-hypertensive or sedative agents and the changes in the vital signs before and after transportation in a Dr. Heli were also analyzed in each group.

The data were analyzed using the unpaired or paired Student's *t*-test for variables displaying normal distribution, the Wilcoxon test for non-parametric variables,

and the chi-squared test or contingency table analyses for categorical variables. Sample size calculations were not performed. The data were expressed as the mean ± standard deviation (SD) or median (interquartile range) for continuous variables, and the number (percentages) for categorical variables. P values of <0.05 were considered to indicate statistical significance.

The Dr. Heli service was first implemented in Japan by the Kawasaki Medical School. The service was called “Dr-Heli” to emphasize the fact that doctors are onboard the helicopter and fly to the patients to provide treatment as quickly as possible. The crews of physician-staffed helicopters generally consist of 1 pilot, 1 mechanic, 1 doctor, and 1 nurse. Our hospital in eastern Shizuoka prefecture began to provide a Dr. Heli service in 2004. Since then, the service has been used to directly transport patients with suspected stroke, including patients with subarachnoid hemorrhage (SAH), from the scene to a medical facility [1]. The helicopter used by the Dr. Heli service in Eastern Shizuoka, which is jointly produced by Messerschmitt-Bölkow-Blohm in Germany and Kawasaki in Japan, is known as the BK 117; the Eurocopter EC 145 is based on this design. Eastern Shizuoka is a mountainous region of approximately 4,090 km^2 in size, which has a population of approximately 2 million and few hospitals [1]. The journey from the southern tip of the peninsula to the critical care medical

center of our hospital takes 1.5 hours by ambulance using a windy road that crosses over mountain passes. In contrast, this trip only takes 15 minutes by helicopter. [1] The road often becomes congested because eastern Shizuoka is a sightseeing resort area that is located near Tokyo. Only the fire department and doctors in hospitals that have a heliport can request the dispatch of a Dr. Heli for critically ill patients including trauma patients.

In Japan, local governments have established the emergency medical system (EMS) as a public service, and anyone can call an ambulance free of charge by dialing 119. Most local governments use a one-tier emergency system. Usually, the fire department dispatches the EMS team (three emergency medical technicians) in an ambulance after receiving a 119 call. Recently in Japan, emergency medical technicians, who can secure a venous route, secure an airway with instruments and inject adrenaline for patients in cardiac arrest, have been allowed to inject adrenaline for patients with anaphylactic shock, infuse glucose to patients with hypoglycemia and to secure a venous route for patients with unstable circulation. When emergency medical technicians cannot decide how to treat patients, they can consult a doctor in a hospital by telephone. However, until April 2016 in Shizuoka Prefecture, emergency medical technicians were not allowed to secure a patient’s airway using instruments, establish a

venous route, or prescribe drugs for patients who are not in cardiac arrest [13]. They could only administer oxygen, provide supportive ventilation using a self-inflated bag-mask and manage the patient's position (sitting, supine or lateral position). Of note, they still cannot administer anti-hypertensive agents to patients with hypertension. Accordingly, the changes in the patients' vital signs have been controlled by Dr. Heli staff, as opposed to emergency medical technicians (who would be providing care for patients transported in a ground ambulance).

3. Results

There were 108 cases in which SAH was diagnosed in patients transported by a Dr. Heli during the investigation period. The following cases were excluded from the study: cases in which the patient was transported to another medical facility by a Dr. Heli (n=15); and cases in which SAH was found to have been induced by trauma (n=3). After excluding these cases, the 90 remaining cases were enrolled in the present study. There were no cases in which SAH was invisible on CT, but visible on MRI. The Scene and Interhospital groups included 46 subjects and 44 subjects, respectively. All subjects in the Interhospital group had SAH diagnosed by CT and transported to local hospital by ground ambulance.

Table 1 shows the results of an analysis of the two groups. There were no significant differences between the two groups with regard to the age, sex, heart rate, ratio of tracheal intubation and change of condition. Seven subjects in the Interhospital group had already received tracheal intubation by the staff at their local hospital. However, the systolic blood pressure, percentage of cardiac arrest, and Fisher classification values of the patients in the Scene group were significantly greater than those in the Interhospital group. The Glasgow Coma Scale and the percentage increase of systolic blood pressure during transportation in the Scene group than in were significantly lower than those in the Interhospital group.

The reasons for calling for a Dr. Heli in the Scene group are as follows: unconsciousness (n=35), severe headache (n=22), hemiparesis (n=2), dysarthria (n=1), and convulsion (n=1). Among them, a total of seven subjects in the Scene group had hemiparesis confirmed by the staff of the Dr. Heli.

As the percentage of cardiac arrest in the Scene group was significantly greater than that in the Interhospital group, we excluded the subjects who had cardiac arrest prior to Dr. Heli transportation, since all of the patients with cardiac arrest underwent infusion of adrenaline (pressor agent) and tracheal intubation. In all of the cases involving patients who were in cardiac arrest, cardiac arrest occurred before they were

contacted by the staff of the Dr. Heli. However, from the perspective of preventing re-bleeding of an aneurysm, controlling the blood pressure was important for patients with SAH, so the methods of managing the circulation differed completely between the patients with and without cardiac arrest.[14,15] There were eight subjects with cardiac arrest (seven in the Scene and one in the Interhospital group), all cases recovered their circulation, and all but one (the Scene group) eventually died despite aggressive treatment. After excluding these subjects, there were no significant differences between the two groups with regard to age, sex, heart rate, ratio of tracheal intubation, change of condition and proportion using sedative agents (**Table 2**). However, the systolic blood pressure and Fisher classification values of the Scene group were still significantly greater than those in the Interhospital group. The proportion of patients to whom an anti-hypertensive agent was administered was significantly smaller in the Scene group than in the Interhospital group. All anti-hypertensive agents were nicardipine, which was the only drug available in the Dr. Heli. Although the Glasgow Coma Scale in the Scene group was lower than that in the Interhospital group, the difference was not statistically significant.

Table 3 shows the changes in the vital signs before and after transportation via Dr. Heli in the Scene and Interhospital group after excluding the patients with cardiac

arrest. The analyses showed that the systolic blood pressure after transportation to a hospital was lower than that before transportation. Furthermore, the systolic blood pressure in the Scene group was significantly greater than that in the Interhospital group (149.5 ± 22.1 vs. 124.1 ± 22.1 mmHg, $p<0.0001$). The heart rate after transportation in the Scene group was significantly greater than before, while no such difference was seen in the Interhospital group. Both analyses showed that there was no significant difference in the Glasgow Coma Scale, even when including subjects with tracheal intubation.

Table 4 shows the final outcome of the analysis of the whole study population and the analysis with the exclusion of cardiac arrest patients. There were no significant differences between the two groups with regard to Glasgow Outcome Score and survival ratio even including cardiac arrest patients.

4. Discussion

The present study demonstrated that the severity of SAH in the Scene group was greater than that in the Interhospital group. However, there was no difference in the outcomes of the patients in the two groups. Accordingly, this result indirectly suggests the safety of using a Dr. Heli to evacuate SAH patients from the scene. The

changes in the patients' vital signs were the result of medical interventions provided by the Dr. Heli staff, as opposed to the emergency medical technicians (whose interventions were limited based on their scope of practice). Thus, most of the patients were safely transported to our hospital. This may explain why there was no difference in the final outcomes of the two groups, despite the fact that the severity of SAH in the Scene group was greater than that in the Interhospital group. Silbergleit et al. analyzed patients with acute intracranial bleeding (including SAH) who underwent interhospital transportation by air and reported that emergency air medical transfer for definitive neurosurgical care appeared to be both safe and effective because the patients who were transported after eight hours of the onset of symptoms had lower GCS scores. However, the outcome measures were not significantly different from those who were transported later [16].

The main cause of non-traumatic SAH was a ruptured cerebral aneurysm. The main cause of fatalities in the acute phase in patients with ruptured cerebral aneurysm is the rebleeding of a cerebral aneurysm in patients who survive the initial attack. [14,15, 17-19] The rebleeding of a cerebral aneurysm results in an increase in the volume of subarachnoid hemorrhage, which is followed by a deterioration of consciousness, respiratory arrest and death. In this study, two cases in the Scene and one case in the

Interhospital group had a deterioration of consciousness and respiratory arrest during transportation, these cases might have experienced rebleeding. Hypertension is the main cause of the rebleeding of cerebral aneurysms. [17] Nineteen percent of the patients in the Scene group and 43% of the patients in the Interhospital group had an increase of blood pressure during flights. Vibration, noise and restraint in a narrow space tend to be associated with an increases in both heart rate and blood pressure. [20] Thus, the blood pressure of patients may increase during flights, which might cause the rebleeding of a cerebral aneurysm. As the patients in the scene group showed more severe consciousness impairment than those in the Interhospital group, it is possible that the subjects in the Interhospital group experienced stress in relation to the flight. This may explain the different rates of blood pressure increase in the two groups.

Concerning the vital signs before and after transportation using the Dr. Heli after excluding subjects with cardiac arrest, the blood pressure was controlled by medical treatments. This medical intervention provided by the staff of the Dr. Heli may have contributed to the reduction in the occurrence of rebleeding of aneurysms and obtaining favorable outcomes. The difference in the values between the Scene and Interhospital groups may be due to whether or not a definitive diagnosis of SAH was obtained. The subjects of the Interhospital group were definitively diagnosed with

SAH by CT at their local hospital, so their blood pressure was strictly controlled using anti-hypertensive agents. In addition, those in the Interhospital group were initially seen at another facility where the staff was given time to stabilize the patient, while the patients in the Scene group were assessed by emergency medical technicians whose options were limited. However, the subjects in the Scene group were suspected of having suffered a stroke, including ischemic stroke, so strict control of the blood pressure was not necessarily warranted.[19] Furthermore, the heart rate after transportation in the Scene group was faster than that before, a possible side effect of nicardipine or a stress reaction due to the air evacuation. [20] However, the heart rate before and after transportation in the Scene group was directly evacuated from the scene while the subjects in the Interhospital group were transported to a local hospital. Accordingly, instability in the autonomic nervous function in the hyperacute phase of SAH may have affected the heart rate of the subjects in the Scene group. [22]

The present study demonstrated a higher proportion of cardiac arrest among the patients in the Scene group in comparison to the Interhospital group. After excluding the subjects with cardiac arrest, the severity of the condition of the patients in the Scene group was still greater than that in the Interhospital group. The Dr. Heli service only operates during the day. Accordingly, the patients who suffered cardiac arrest or

severe subarachnoid hemorrhage at night or during poor weather (when the Dr. Heli service was unavailable) were transported to nearby local medical facilities. Some of the local medical facilities who admitted such patients did not call the Dr. Heli or send a ground ambulance to our hospital, until a patient with cardiac arrest could obtain spontaneous circulation, or a patient with severe SAH showed signs that are associated with a poor prognosis, such as fixed, dilated pupils and respiratory arrest in deep coma. In addition, the condition of the patients in the Scene group was severe enough to warrant transportation direct from the scene, while the that of the patients in the Interhospital group was not—thus, the latter patients were transported locally. These may explain the different background characteristics of the two groups.

The study did not compare the results of transportation using the ground ambulance because there was not such data in the registry data of the Dr. Heli control room in our hospital. A previous report from our hospital that investigated patients who were treated from 2004 to 2007 showed that the Glasgow Coma Scale values of patients who were transported by Dr. Heli were significantly lower than those who were transported by ground ambulance. [24] However, there were no significant differences in the Glasgow Outcome Scores of the two groups at discharge. Indirectly, this supports the conclusion that the Dr. Heli service was considered to be a safer means of

transporting SAH patients. In addition, there was no cases of rebleeding among the 47 subarachnoid hemorrhage patients who were transported between hospitals using the Dr. Heli service. [24] In contrast, an analysis of head CT images before and after transportation revealed rebleeding in 17 of the 126 patients who were transported by the ground ambulance. Japan's Emergency Medical Network of Helicopter and Hospital now prospectively collects patient data, including the data of SAH patients who are evacuated from the scene by the Dr. Heli or ground ambulance; thus further study is needed to investigate the usefulness of evacuating patients with suspected SAH from the scene. In particular, the data on the severity of their SAH or the time between the onset of symptoms and reaching the hospital should be analyzed.

The present study is associated with several limitations. First, due to the small sample size and the final outcome (survival ratio and functional outcome) we did not observe a significant difference between the two groups; thus it may be difficult to conclude that the outcomes were primarily attributed to the Dr Heli service. Secondly, this study did not directly compare outcomes of SAH patients who were transported by ground ambulance, in whom the vital signs could not be controlled before cardiac arrest, in order to compare the neurological outcomes. Thirdly, we cannot exclude the possibility of a selection bias. Fourthly, it was not possible to identify SAH in any

definitive way on the scene. Due to retrospective nature of the study, we could not determine the exact number of suspected SAH or stroke patients who had been transported from the scene who were not finally diagnosed with SAH or stroke. The cost-effective strategy is also required for management of the Dr Heli. Finally, there is a significant risk of Type II error, limiting the conclusions. Further large human studies are thus warranted to determine the indications for using the Dr Heli service to transport SAH patients.

5. Conclusion

This study suggested the safety of using a Dr. Heli to evacuate SAH patients from the scene.

When contents of the first call suggest the possibility that a patient has SAH (such as sudden onset headache with unconsciousness), direct evacuation from the scene using a physician-staffed helicopter may be warranted. Future studies should be conducted to determine if direct evacuation from the scene or initial stabilization prior to transport improves the outcomes of SAH patients.

Conflict of Interest

The authors declare no conflicts of interest in association with the present study.

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Table 1. The results of the analysis of the whole study population

	Scene (n=46)	Interhospital (n=44)	p-value
Age	68.7 ± 13.5	68.3 ± 12.8	n.s.
Male/Female	15/31	9/35	n.s.
Glasgow Coma Scale	7 (11)	14 (11)	$p<0.05$
Systolic blood pressure	151.5 ± 62.4	140.4 ± 35.3	$p<0.05$
Heart rate	78.4 ± 31.6	81.0 ± 14.5	n.s.
Proportion of cardiac arrest	7 (15.2%)	1 (2.2%)	$p<0.05$
Tracheal intubation	19 (30.7%)	12 (25.6%)	n.s.
Change of condition	22 (47.8%)	25 (56.8%)	n.s.
Vomiting	10 (21.7%)	6 (13.6%)	n.s.
Increase of blood pressure	9 (19.5%)	19 (43.1%)	$p<0.01$
Decrease of blood pressure	0	2 (4.5%)	n.s.
Decrease of respiratory rate	1 (2.1%)	1 (2.2%)	n.s.
Deterioration of consciousness	1 (2.1%)	0	n.s.
Fisher classification	3.5 (3)	3 (3)	$p<0.05$

n.s.: not significant

Table 2. The results of the analysis with the exclusion of cardiac arrest patients

	Scene (n=39)	Interhospital (n=43)	p-value
Age	69.7 ± 13.6	68.0 ± 12.8	n.s.
Male/Female	9/30	9/34	n.s.
Glasgow Coma Scale	11 (9)	14 (9.5)	n.s. (p=0.1)
Systolic blood pressure	168.0 ± 39.2	143.0 ± 31.5	p<0.01
Heart rate	84.1 ± 19.6	81.8 ± 13.7	n.s.
Tracheal intubation	12 (30.7)	11 (25.6)	n.s.
Change of condition	21 (53.8%)	25 (58.1%)	n.s.
Use of an anti-hypertensive agent	18 (46.1%)	38 (88.3%)	p<0.0001
Use of a sedative agent	10 (25.6%)	12 (27.9%)	n.s.
Fisher classification	3 (3)	3 (3)	p<0.05

n.s.: not significant

Table 3. Changes in the vital signs before and after transportation using the Dr. Heli in the Scene group and Inter hospital group after excluding patients with cardiac arrest

Scene group (n=39)

	Before	After	p value
Systolic blood pressure (mmHg)	168.0 ± 39.2	149.3 ± 22.5	$p < 0.01$
Heart rate (rate/minute)	84.1 ± 19.6	91.5 ± 21.2	$p < 0.05$
Glasgow Coma Scale	11 (9)	6 (11)	n.s.($p=0.1$)
Excluding tracheal intubation (n=27)	14 (5)	13 (8.5)	n.s.

Interhopital group (n=43)

	Before	After	p value
Systolic blood pressure (mmHg)	141.8 ± 32.1	124.1 ± 24.4	$p < 0.001$
Heart rate (rate/minute)	81.9 ± 13.5	84.5 ± 16.3	n.s.
Glasgow Coma Scale	14 ± 9.5	13 ± 8	n.s.
Excluding tracheal intubation (n=32)	14 ± 2.75	14 ± 2	n.s.

n.s.: not significant

Table 4 The final outcome of the analysis of the whole study population and the analysis with the exclusion of cardiac arrest patients

Whole study population

	Scene (n=46)	Interhospital (n=44)	p-value
Glasgow Outcome Score	3 (3)	3.5 (3)	n.s.
Survival ratio	34 (73.9%)	36 (81.8%)	n.s.

Exclusion of cardiac arrest patients

	Scene (n=39)	Interhospital (n=43)	p-value
Glasgow Outcome Score	4 (2)	4 (3)	n.s.
Survival ratio	33 (84.6 %)	36 (83.7%)	n.s.

n.s.: not significant