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Effects of a Physician-Staffed Helicopter Emergency Medical Service on Cerebral Infarction Outcomes: A Registry-Based Observational Study

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Background: The effects of helicopter emergency medical services on the treatment of cerebral infarction remains unclear. We investigated the effects of helicopter transport on outcomes in patients with cerebral infarction.

Methods: This study included 1,246 patients with cerebral infarction who were assigned to two groups: patients transported by "Doctor-Heli" (DH group) and patients transported by ground ambulances (GA group). Cerebral performance category (CPC), overall performance category (OPC), and in-hospital mortality were evaluated. Multivariate logistic regression analysis was used to adjust for background factors and evaluate a subgroup of patients with severe cerebral infarction (i.e., a National Institutes of Health Stroke Scale (NIHSS) score >10).

Results: The DH group included more patients with severe cerebral infarction. No difference was observed in the interval from illness onset to recombinant tissue plasminogen activator treatment between the groups; however, the interval from illness onset to interventional radiology (IR) was significantly shorter in the DH group. The DH group had a lower CPC than the GA group, but there was no significant difference in OPC. Multivariate logistic regression analysis showed that the odds ratio of DH transport for OPC1-2 was 2.33. Subgroup analysis of severe cases yielded odds ratios of 2.19 and 2.62 for CPC1-2 and OPC1-2 respectively.

Conclusion: The DH group included patients with severe cerebral infarction living in remote areas and provided with emergency IR treatment. This analysis suggested that DH transport improves OPC and CPC, particularly in patients with an NIHSS scores of >10. (J Nippon Med Sch 2025; 92: 391–398)

Key words: helicopter emergency medical service, stroke, cerebral infarction

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Introduction

Prompt emergency treatment is crucial for patients with cerebral infarction, as it directly affects clinical outcomes. Patients require rapid transportation to minimize the time to initiation of recombinant tissue plasminogen activator (rt-PA) treatment and cerebral thrombectomy therapy after stroke onset. Moreover, patients with cerebral infarction should be transported to core facilities equipped with the necessary medical resources and technology. Although transportation by helicopter enables patients with cerebral infarction to receive emergency treatment, resulting in improved neurological outcomes and life expectancy, no large-scale study has assessed the impact of helicopter transportation on neurological outcomes in patients with cerebral infarction.

The first helicopter emergency medical service (HEMS) was developed in 1952 by Rega (Switzerland). HEMSs with doctors and nurses on board, also called "Doctor-Heli" (DH), were implemented in Japan in 2001 and deployed at 57 sites as of May 2024. DHs are essential social infrastructure, and over 20,000 missions are dispatched annually. In this study, led by the Japanese Society for Aeromedical Services, we analyzed data from patients with cerebral infarction in the DH registry from 2015-2018 and determined the effect of DH transport on patient outcomes.

Materials and Methods

This retrospective study analyzed data that were collected during the period 2015-2018 and stored in the DH registry, which includes almost all DH base hospitals in Japan. We targeted cases of DH transport of patients from the emergency scene directly to base hospitals and excluded transports of patients between medical facilities, because the primary purpose of DHs in Japan is to transport patients from emergency scenes directly to base hospitals. The DH registry focuses on patients with five conditions: trauma, acute coronary syndrome (ACS), cerebral hemorrhage, subarachnoid hemorrhage, and cerebral infarction. To understand the operational situation of each of these five conditions, we gathered information on the time of request, time spent at the scene, transport time, and patient age, sex, and vital signs. We also included information on onset time, severity, in-hospital treatment, treatment duration, hospitalization status at 4 weeks after hospital admission, cerebral performance category (CPC), overall performance category (OPC), and presence and duration of intensive care unit (ICU) admission. To compare the DH transport group with another group, we used the same variables to directly evaluate cases of ground ambulance (GA) transport of patients from emergency scenes to base hospitals between the hours of 8:00 and 18:00 (nationwide DH operating hours). In other words, this group included patients for whom helicopter transport was not possible because of the short distances, bad weather, and overlapping missions, among other reasons. We also evaluated National Institutes of Health Stroke Scale (NIHSS) score, use of rt-PA and vascular interventional radiology (IR) as radical treatments, and administration of anticoagulants and antiplatelet medication for cerebral infarction, which was the primary focus of this study.

The Japan Coma Scale (JCS)[1] is widely used to evaluate consciousness in emergency situations. It uses an assessment scale of 0-300 to determine a patient's consciousness level on the basis of the eye-opening response to stimulation. This study focused on three consciousness levels: patients who could open their eyes without stimulation (0-3), patients who could open their eyes with stimulation (10-30), and patients who could not open their eyes (100-300). We used the JCS to evaluate patients' consciousness level in emergency situations and the Glasgow Coma Scale (GCS) to assess consciousness at the time of hospital arrival.

Primary outcomes were CPC and OPC of patients at 4 weeks after hospital admission, and the secondary outcomes were survival status at 4 weeks after hospital admission and length of stay in the ICU. As background information, we recorded patient age, sex, and vital signs (systolic arterial pressure, pulse, respiration rate, and JCS) at the time of first contact with the emergency crew; NIHSS score upon hospital arrival; transportation distance; minutes elapsed from ambulance request to emergency crew arrival; and administration of anticoagulant and antiplatelet medication, rt-PA, and endovascular treatment. We then compared the results between the DH and GA groups.

We used multivariate logistic regression analysis because there were significant differences in background factors. The following characteristics were included as independent variables: patient age, sex, systolic arterial pressure, GCS score, NIHSS score, administration of rt-PA and IR treatment upon hospital arrival, use of DH, and transport distance. In our analysis, we established a subgroup with severe cerebral infarction (defined as NIHSS score >10). We used data on the number of cases (%), average values, and median values. A p value of <0.05 was considered to indicate statistical significance when using the Mann-Whitney U test for continuous variables and the $\chi 2$ test for categorical variables (IBM SPSS Version 25).

All methods were performed in accordance with the relevant guidelines and the principles of the Declaration of Helsinki[2]. This study was approved by the Institutional Review Boards of Tokai University (Approval No. 14R-223), Nippon Medical School Chiba Hokusoh Hospital (Approval No. 461), and the Japanese Society for Aeromedical Services (approval number not available). All human clinical data in this study were anonymized. Informed consent was obtained from the patients using an opt-out procedure, as approved by the Ethics Committee of Nippon Medical School Chiba Hokusoh Hospital.

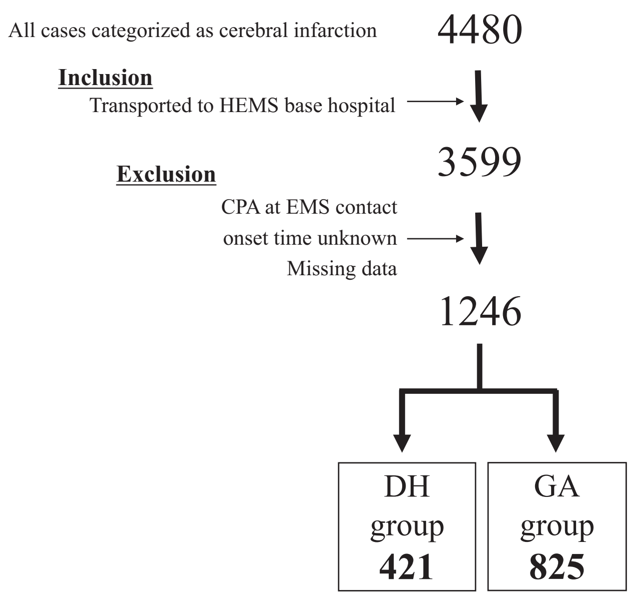

Fig. 1 Study flowchart

Results

Of the 4,480 patients with a registered final diagnosis of cerebral infarction, 3,599 were transported to base hospitals. We excluded patients with cardiac arrest at physical contact with the emergency crew, those with an unidentified onset time, and those missing essential data for analysis. Ultimately, we analyzed data from 421 DH group cases and 825 GA group cases (**Figure 1**).

Table 1 summarizes the characteristics of the 421 DH cases and 825 GA cases. The DH group had a significantly longer transport distance than the GA group (33.80 km vs 7.00 km; p <0.001) and a significantly shorter duration from illness onset to emergency call (37.00 min vs 57.00 min; p <0.001) but a significantly longer duration from emergency call to hospital arrival (54.00 min vs 34.00 min; p <0.001), as compared with the GA group. There was no significant difference in the interval from illness onset to hospital arrival between groups (93.00 min vs 98.00 min; p = 0.461).

The two groups did not differ in systolic blood pressure, pulse, or respiratory rate; however, the DH group had significantly higher JCS scores than the GA group (p <0.001). In terms of hospital arrival, the DH group had a significantly lower GCS score (p <0.001) but a significantly higher NIHSS score than the GA group (11.52 vs 8.6; p <0.001).

Regarding medical treatment during transport, of the 421 patients in the DH group, 9 patients (2.1%) were intubated, 7 patients (1.7%) were sedated, and 35 patients (8.3%) were given depressors; none of the patients in the GA group received such treatment.

Analysis of treatments during the acute stage showed that the DH group had significantly higher rates than the GA group of rt-PA administration (31.8% vs 23.4%; p = 0.002), endovascular treatment (24.2% vs 16.2%; p = 0.001) and ICU admission (40.8% vs 33.7%; p = 0.018). Additionally, no patients in the database received rt-PA in a prehospital setting. Regarding time from illness onset to radical treatment, the two groups did not differ in rt-PA; however, duration of IR was shorter in the DH group than in the GA group (167.00 min vs 197.50 min; p = 0.025). We found no difference in hospital mortality rate (7.4% vs 5.7%; p = 0.288). However, CPC1-2 at 4 weeks after hospital admission significantly differed between groups (p <0.001): there were 251 cases in the DH group (59.6%) and 555 cases in the GA group (67.3%). No difference in OPC1-2 between groups (p = 0.211) was observed: there were 228 cases in the DH group (54.2%) and 480 cases in the GA group (58.2%).

To evaluate outcomes of DH transport at 4 weeks, we conducted logistic regression analysis using CPC1-2, OPC 1-2, and in-hospital mortality as objective variables. The odds ratios were 1.38 (95% CI: 0.89-2.12; p = 0.15) for CPC1-2, 2.33 (95% CI: 1.28-4.24; p = 0.01) for OPC1-2 (**Table 2**), and 0.71 (95% CI: 0.29-1.74; p = 0.46) for in-hospital mortality (**Table 3**).

Analysis of patients with severe cerebral infarction (NIHSS score > 10)[3] yielded an odds ratio of 2.19 (95% CI: 1.12-4.27; p = 0.02) for CPC1-2 and 2.62 (95% CI: 1.27-5.42; p = 0.01) for OPC1-2 (**Table 4**), indicating that both ratios were relevant in DH transport.

Discussion

At the official start of the DH programs (2001), planning

Table 1 Comparison of DH group and GA group

	DH group (n= 421)	GA group (n= 825)	P value
Age	78.00 [69.00, 85.00]	77.00 [68.00, 84.00]	0.005
Gender/male (%)	254 (60.3)	512 (62.1)	0.595
Distance (km)	33.80 [21.10, 49.00]	7.00 [3.901, 2.50]	<0.001
Vital signs (ambulance)			
sBP (mmHg)	159.00 [133.00, 184.00]	160.00 [140.00, 182.00]	0.128
RR (/min)	20.00 [18.00, 23.00]	18.00 [18.00, 20.00]	0.498
HR (/min)	82.00 [70.00, 95.25]	81.00 [70.00, 93.00]	0.913
Japan Coma Scale			<0.001
0-3 (%)	204 (69.9)	684 (86.4)	
10-30 (%)	48 (16.4)	64 (8.1)	
100-300 (%)	40 (13.7)	44 (5.6)	
Duration (minutes)			
onset to EMS	37.00 [9.00, 123.00]	57.00 [14.00, 235.00]	<0.001
EMS to hospital arrival	54.00 [45.00, 65.00]	34.00 [28.00, 44.00]	<0.001
onset to hospital arrival	93.00 [67.00, 180.00]	98.00 [52.00, 275.00]	0.461
Treatment during transportation			
tracheal intubation (%)	9 (2.1)	0	<0.001
sedative drugs (%)	7 (1.7)	0	0.001
depressor drugs (%)	35 (8.3)	0	<0.001
Vital signs (on admission)			
sBp (mm Hg)	154.00 [136.00, 174.00]	159.00 [140.00, 179.00]	0.016
RR (/min)	18.00 [16.00, 22.00]	18.00 [16.00, 22.00]	0.819
HR (/min)	80.00 [69.00, 93.00]	80.00 [70.00, 92.00]	0.64
Glasgow Coma Scale	14.00 [11.00, 15.00]	15.00 [13.00, 15.00]	<0.001
NIHSS	11.52 (9.84)	8.76 (8.78)	<0.001
rt-PA (%)	134 (31.8)	193 (23.4)	0.002
duration onset-rt-PA (min)	142.00 [110.00, 194.00]	140.00 [102.00, 175.00]	0.312
IR (%)	102 (24.2)	134 (16.2)	0.001
duration onset-IR (min)	167.00 [134.00, 232.00]	197.50 [145.00, 179.00]	0.025
ICU admission (%)	168 (40.8)	273 (33.7)	0.018
Hospital stay	18.00 [11.00, 28.00]	16.00 [11.00, 28.00]	0.472
Mortality (%)	31 (7.4)	47 (5.7)	0.288
CPC (%)			<0.001
1	154 (36.6)	429 (52.0)	
2	97 (23.0)	126 (15.3)	
3	130 (30.9)	203 (24.6)	
4	8 (1.9)	22 (2.7)	
5	32 (7.6)	45 (5.5)	
OPC (%)			0.211
1	124 (29.5)	289 (35.0)	
2	104 (24.7)	191 (23.2)	
3	153 (36.3)	276 (33.5)	
4	8 (1.9)	22 (2.7)	
5	32 (7.6)	47 (5.7)	

HEMS: helicopter emergency medical services, CPA: cardiopulmonary arrest, EMS: emergency medical services

for early transport activities was based on data estimated and calculated from the results of air transportation in other countries and the actual transportation of GAs in Japan. Now that the DH operation has been operating for 20 years, treatment quality requires re-evaluation.

The Japanese Society for Aeromedical Services and the DH Effect Review Committee used this background information to create a database that allowed staff to extract data to review the effectiveness of DHs for five conditions: cerebral infarction, cerebral hemorrhage, subarachnoid hemorrhage, ACS, and trauma. A previous study of data collected for ACS and subarachnoid hem-

Table 2 Odds ratio for CPC1-2, OPC1-2 (overall)

	CPC1-2				OPC1-2			
	Odds ratio	95%CI		P value	Odds ratio	95%CI		P value
Variables		lower	upper			lower	upper	
Transport by DH	**1.38**	**0.89**	**2.12**	**0.15**	**2.33**	**1.28**	**4.24**	**0.01**
Age	0.95	0.94	0.97	0.00	0.96	0.94	0.97	0.00
Male	1.08	0.78	1.49	0.63	1.20	0.87	1.65	0.27
sBP on admission	1.00	1.00	1.01	0.77	1.00	0.99	1.00	0.59
GCS on admission	1.09	1.02	1.17	0.02	1.09	1.00	1.19	0.06
Interval from onset to EMS call	1.00	1.00	1.00	0.74	1.00	1.00	1.00	0.65
NIHSS	0.91	0.89	0.94	0.00	0.89	0.87	0.92	0.00
rt-PA	1.18	0.84	1.66	0.35	1.27	0.90	1.80	0.18
IR	1.57	1.04	2.37	0.03	1.65	1.07	2.54	0.02
Distance	0.99	0.98	1.00	0.05	1.01	0.99	1.02	0.54

GCS: Glasgow Coma Scale, EMS: emergency medical services, NIHSS: National Institute of Health Stroke Scale, IR: interventional radiology

Table 3 Odds ratio for in-hospital mortality (overall)

	Odds ratio	95%CI		P value
Variables		lower	upper	
Transport by DH	**0.71**	**0.29**	**1.74**	**0.46**
Age	1.02	0.99	1.05	0.25
Male	1.03	0.53	1.99	0.93
sBP on admission	1.01	1.00	1.02	0.27
GCS on admission	0.88	0.77	1.01	0.06
Interval from onset to EMS call	1.00	1.00	1.00	0.70
NIHSS	1.10	1.06	1.14	0.00
rt-PA	0.38	0.18	0.77	0.01
IR	1.45	0.72	2.91	0.30
Distance	1.00	0.98	1.02	0.85

GCS: Glasgow Coma Scale, EMS: emergency medical services, NIHSS: National Institute of Health Stroke Scale, IR: interventional radiology

Table 4 Odds ratio for CPC1-2, OPC1-2 (NIHSS>10 subgroup)

	CPC1-2				OPC1-2			
	Odds ratio	95%CI		P value	Odds ratio	95%CI		P value
Variables		lower	upper			lower	upper	
Transport by DH	**2.19**	**1.12**	**4.27**	**0.02**	**2.62**	**1.27**	**5.42**	**0.01**
Age	0.95	0.93	0.98	0.00	0.94	0.92	0.97	0.00
Male	1.23	0.73	2.06	0.43	1.13	0.64	2.00	0.67
sBP on admission	1.00	0.99	1.01	0.46	1.00	0.99	1.01	0.61
GCS on admission	1.16	1.04	1.31	0.01	1.16	1.02	1.32	0.02
Interval from onset to EMS call	1.00	1.00	1.00	0.98	1.00	1.00	1.00	0.94
NIHSS	0.96	0.92	1.01	0.14	0.94	0.89	0.99	0.03
rt-PA	2.41	1.46	3.99	0.00	2.38	1.38	4.10	0.00
IR	1.49	0.90	2.45	0.12	1.82	1.06	3.13	0.03
Distance	0.99	0.98	1.00	0.15	0.98	0.97	1.00	0.05

GCS: Glasgow Coma Scale, EMS: emergency medical services, NIHSS: National Institute of Health Stroke Scale, IR: interventional radiology orrhage reported that DH transport did not improve outcomes in ACS cases and that spontaneous resuscitation rates were higher in patients who experienced cardiopulmonary arrest[4]. Furthermore, DHs transported many patients with high-grade subarachnoid hemorrhage. The outcomes were poor, and it was unclear if DH transport led to functional or outcome improvements[5]. The present study extracted data on cerebral infarction from the aforementioned database and is the largest Japanese study to examine DH effectiveness.

The design of our study considered the characteristics of DHs, emergency medical systems, and emergency medical care operations related to cerebral infarction in Japan, which include the following:

1. Night flights are not conducted because DHs require visual flight.
2. Physicians and nurses on DHs can administer antihypertensives and sedatives and perform tracheal intubation.
3. Emergency crews and paramedics can only conduct physical examinations and glucose measurements.
4. Medical systems, such as mobile stroke units that provide stroke assessment and on-scene imaging diagnosis, are not widespread.

The present findings revealed that emergency care for cerebral infarction involved fewer on-scene medical treatments provided by dispatched physicians and more land transport than emergency care for other conditions.

A comparison of the DH and GA groups revealed that the DH group had significantly longer transport distances than the GA group (33.80 km vs 7.00 km; $p < 0.001$), and that DHs targeted patients in remote areas. These findings were true for all five medical conditions. Because the registered data were limited to cases of transport to DH base hospitals, the DH group included patients transported from nearby and remote areas; however, the GA group primarily included patients transported from nearby regions.

Regarding disease severity, consciousness level was lower in the DH group during the interval from physical contact with the emergency crew to hospital arrival, but NIHSS was significantly higher than in the GA group (11.52 vs 8.76; $p < 0.001$). Furthermore, the DH group had a significantly higher rate of admission for emergency treatments, such as rt-PA (31.8% vs 23.4%; $p = 0.002$) and IR (24.2% vs 16.2%; $p = 0.001$). These findings suggest that the DH group had more severe disease but that other factors such as physician selection of hospitals that could provide early treatment and preparations for fundamental treatment based on accurate information, contributed to the results. Whie planning this study, we were concerned about possibility of significant differences in transport distance, elapsed time, and disease severity between the DH and GA groups. Therefore, we performed logistic regression analysis using these factors as independent variables.

Logistic regression analysis showed no relationship between CPC1-2, neurologically satisfactory outcomes (a primary evaluation factor), and DH transport in any cohort. However, OPC1-2 and DH transport were significantly associated. Therefore, we created a patient subgroup with an NIHSS score >10, and logistic regression analysis revealed a significant association between CPC1-2 and OPC1-2 in the DH group.

To our knowledge, few studies have described the positive impact of cerebral infarction treatment using physician-staffed HEMSs on neurological and functional outcomes[6–8]. Only 5 of 30 studies reviewed by Tal and Mor in 2020[9] reported a relationship with outcomes, but no study identified outcome improvement. The DH registry was constructed to verify the effectiveness of DH transport for five medical conditions (trauma, subarachnoid hemorrhage, intracranial hemorrhage, acute coronary syndrome, cerebral infarction). Outcomes common to these five diseases, including CPC, OPC, and mortality rate, were registered, and the present study analyzed these outcomes. The modified Rankin scale[3,6,7,8,10,11] and Glasgow Outcome Scale were often used in past studies of the outcome of cerebral infarction, but we did not collect these data and thus were unable to include them in the analysis. DH transportation improved neurological and systemic functional outcomes in the NIHSS score >10 subgroup, owing to earlier physician contact with the DH patients. However, the DH group had low prehospital treatment rates, including advanced airway interventions (2.1%), blood pressure management (8.3%), and sedation (1.7%) which suggests that this was not the only factor contributing to improvement. We found no significant difference in the interval from illness onset to hospital arrival between the two groups, but confirmed that the DH group had a significantly shorter elapsed time from illness onset to IR than the GA group. Doctors provided early treatment to patients in the DH group and made appropriate decisions regarding the need for radical treatments such as rt-PA and IR. Thus, early intervention may have contributed to these results. Previous studies also reported that a physician-staffed HEMS shortens radical treatment time[10,12] and accelerates access to medical facilities where patients can receive such treatments[11,13].

This nationwide registry-based study analyzed DH activities in Japan and examined the effects of the current DH transport system, thus providing valuable information. However, we discovered that numerous data were unreported, such as JCS score, GCS score, and respiratory rate, during data collection. Indeed, 25% of the data for NIHSS—the only scale for cerebral infarction—were missing. Therefore, only 421 patients in the DH group and 825 patients in the GA group were examined.

This study had other limitations that warrant mention. First, it was not population based and was limited to patients transported to DH base hospitals. Second, data on adverse events associated with DH transport were not collected, so analysis was not possible. Third, each base hospital had different treatment levels and guidelines. Fourth, we observed significant changes in treatment, because of the widespread use of IR and thrombus aspiration therapy. Last, each emergency crew could decide whether to request a DH after patient assessment.

On the basis of previous results and data collection procedures, the Japanese Society for Aeromedical Services updated and improved its database for high-quality data collection. Further case accumulation will enable future reassessment of cerebral infarction because illness assessment requires relatively simple data.

In summary, DH transport can potentially improve neurological and functional outcomes in patients with cerebral infarction, especially in those with an NIHSS score >10. The advantages of DH transport include early blood pressure control, airway management, timely transport of patients from long distances, provision of appropriate information to medical institutions and promotion of in-hospital treatment preparation. We believe that the significant difference was observed between OPC and CPC in the present critically ill patients is evidence of the advantages of DH transport, but it remains a challenge to identify which factors are most important. Further studies using higher quality data are thus required.

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