

Helicopter Transport for Patients with Cerebral Infarction in Rural Japan

Tatsuya Ueno, MD, PhD,* Haruo Nishijima, MD, PhD,† Hiroki Hikichi, MD,*
Rie Haga, MD, PhD,* Akira Arai, MD, PhD,* Chieko Suzuki, MD, PhD,†
Jin-ichi Nunomura, MD, PhD,* Kyoji Saito, MD,‡ and
Masahiko Tomiyama, MD, PhD†

Objectives: Physician-staffed helicopter transport is faster than ground transport and allows for prompt medical care of patients in rural areas. In this study, we evaluated the relationship between helicopter transport and the prognosis of patients with acute cerebral infarction in rural Japan. *Methods:* This retrospective, observational study included 546 patients with acute cerebral infarction attending Aomori Prefectural Central Hospital, which serves a rural region of Japan. Patients were separated into 2 transport groups: physician-staffed helicopter emergency medical services and ground emergency medical services. Patients were assessed for stroke severity, treatment, and prognosis. *Results:* Of the 546 patients, 11.2% were transported by physician-staffed helicopter emergency medical services and 88.8% by ground emergency medical services. Although the distance transported was significantly longer in the physician-staffed helicopter emergency medical services group, the time from onset to reaching our hospital was similar between the groups. National Institutes of Health Stroke Scale on admission and final prognosis were significantly worse with physician-staffed helicopter emergency medical services than with ground emergency medical services. Multivariate analysis showed no association between transport system and prognosis. *Conclusions:* In this study, patients transported by physician-staffed helicopter emergency medical services had more severe stroke symptoms and poorer functional outcomes than those transported by ground emergency medical services. However, the transport time was shorter for physician-staffed helicopter emergency medical services; thus, physician-staffed helicopter emergency medical services may be useful for reducing transport time for patients in rural Japan.

Key Words: Emergency medical services—helicopter—prognosis—cerebral infarction—stroke—rural health

© 2019 Elsevier Inc. All rights reserved.

Introduction

Guidelines for cerebral infarction recommend initiating intravenous alteplase and mechanical thrombectomy within 4.5 hours and 6 hours, respectively, of onset of symptoms of cerebral infarction.¹ Such treatment may not be available to patients with cerebral infarction living in rural areas because thrombolytic treatment requires expertise, knowledge, and resources, which are not available in all hospitals. Helicopter emergency medical services (HEMS) provide a significantly shorter transport time than ground emergency medical services (GEMS),^{2,3} and have allowed for patients with cerebral infarction in rural regions to receive thrombolytic therapy.^{4,5} Furthermore,

From the *Department of Neurology, Aomori Prefectural Central Hospital, Aomori, Japan; †Department of Neurology, Hirosaki University Graduate School of Medicine, Hirosaki, Japan; and ‡Department of Emergency Medicine, Aomori Prefectural Central Hospital, Aomori, Japan.

Received April 26, 2019; revision received May 28, 2019; accepted June 9, 2019.

Address correspondence to Tatsuya Ueno, MD, PhD, Department of Neurology, Aomori Prefectural Central Hospital, 2-1-1 Higashi-Tsukurimichi, Aomori 030-8551, Japan. E-mail:

tatsuya_ueno@med.pref.aomori.jp.

1052-3057/\$ - see front matter

© 2019 Elsevier Inc. All rights reserved.

<https://doi.org/10.1016/j.jstrokecerebrovasdis.2019.06.010>

HEMS for acute cerebral infarction is cost effective.^{6,7} The emergency physician on physician-staffed helicopter transport (PHT) can provide prompt onsite medical care. In Japan, PHT reportedly improves survival of patients with life-threatening trauma;^{8,9} however, to our knowledge, no studies have evaluated the usefulness of PHT in patients with cerebral infarction in Japan. Therefore, in this study, we aimed to evaluate the relationship between HEMS and functional prognosis in patients with acute cerebral infarction in rural Japan.

Materials and Methods

This retrospective observational cohort study was conducted at Aomori Prefectural Central Hospital in Aomori prefecture, which is located in northern Japan, between January 2014 and December 2017. Aomori prefecture is considered a rural area, has a population of 1.27 million, and is divided into 6 secondary medical care zones. There are 3 tertiary centers in Aomori prefecture: Hirosaki University Graduate School of Medicine, Hachinohe City Hospital, and Aomori Prefectural Central Hospital (Fig 1). Our hospital provides medical services to approximately 296,000 people; PHT was initiated in 2011 and costs 210 million yen per year.

In Japan, local governments have established a public emergency medical service: anyone can call an ambulance free of charge by dialing 1-1-9, which connects directly with a dispatch center located in the regional fire defense headquarters. On receipt of an emergency call, the nearest available emergency medical system team is usually sent to the incident by an ambulance. HEMS has been provided in Japan since 2001. In Aomori prefecture, patients can make emergency calls by dialing 1-1-9 but cannot request PHT directly; the fire department receiving the emergency call assesses the need for PHT. The indications for PHT used by the fire department for patients with neurological emergencies are headache of sudden onset, hemiplegia, dysarthria of sudden onset, persistent convulsions, and loss of consciousness. The final decision for

PHT dispatch is made by comprehensive assessment based on the occurrence of a neurological emergency, distance between the incident and our hospital, and whether the patient's condition is such that they could be managed at a rural medical service. Additionally, helicopter transport may be unavailable because of bad weather, the fire service is closed (out of hours), or all helicopters have been dispatched to transport other patients.

We divided patients into 2 groups: those who received PHT (HEMS), and those who received road ambulance transport (GEMS). An emergency physician always accompanied HEMS, whereas emergency paramedical staff accompanied GEMS. Exclusion criteria were as follows: incomplete data, walk-in patient, and onset of cerebral infarction in hospital. The severity of the cerebral infarction was assessed by certified neurologists using the National Institutes of Health Stroke Scale (NIHSS). We used the Trial of ORG 10172 in Acute Stroke Treatment classification and the modified Rankin Scale (mRS) score to assess stroke type and prognosis, respectively.^{10,11} We defined a good prognosis as mRS 0-2, the mRS being evaluated on completion of rehabilitation or when the patient was discharged home. Additionally, we evaluated the following variables: age, sex, comorbidity, stroke type according to Trial of ORG 10172 in Acute Stroke Treatment, time from onset to reaching hospital, time from emergency call to reaching hospital, distance transported, recombinant tissue plasminogen activator (rt-PA) use, thrombectomy, NIHSS score on admission, final mRS score, interval between onset and final day of mRS score evaluation, good prognosis, and mortality.

We used SPSS version 25 (SPSS Japan, Tokyo, Japan) for statistical analyses. We used Fisher's exact test or the χ^2 test depending on the expected frequency for categorical variables and the Mann-Whitney *U* test for continuous variables (because the Shapiro-Wilk's test does not address normal distribution). We considered that $P < .05$ denoted statistically significant. We used stepwise logistic regression analysis to predict good prognosis; we performed this by optimizing the Akaike information criterion using R 2.8.1 (<http://cran.ism.ac.jp>). We used the model χ^2 likelihood-ratio test and Hosmer-Lemeshow goodness of fit test to determine the adequacy of the model. For logistic regression analysis, we categorized age and NIHSS score on admission into 2 categorical variables based on the corresponding median. We defined comorbidity as having at least one of following: hypertension, diabetes mellitus, dyslipidemia, heart failure, ischemic heart disease, atrial fibrillation, stroke, or current smoker. We defined acute treatment on the basis of the use of rt-PA or thrombectomy. Finally, we included the following variables as predictors in the model: age ≥ 76 years, sex (male), HEMS, comorbidity, NIHSS score ≥ 7 , and acute treatment.

This study was performed in accordance with the Helsinki Declaration, and was approved by the ethics committee of Aomori Prefectural Central Hospital, Japan.

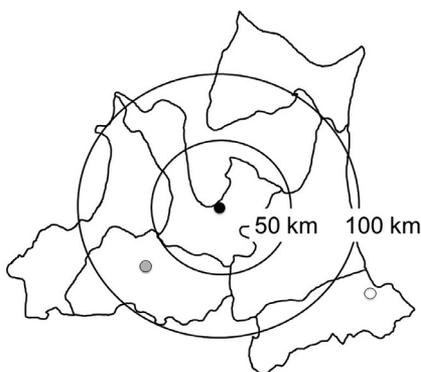


Figure 1. The 3 tertiary centers in Aomori prefecture. Dark circle: Aomori Prefectural Central Hospital; grey circle: Hirosaki University Graduate School of Medicine; white circle: Hachinohe City Hospital.

Because this study was a retrospective observational study, written informed consent was not obtained from the patients. However, we gave patients the opportunity to opt out of the study (<https://aomori-kenbyo.jp/images/uploads/2018/12/noukokusoku12.4.pdf>).

Results

We examined data of 1216 consecutive patients with acute cerebral infarction. Complete datasets were obtained from 546 patients; their clinical characteristics are shown in Table 1. The median age was 76 years, and the male to female ratio was 1.45:1. Of the 546 patients, 11.2% of patients were transported by HEMS and 88.8% by GEMS (Table 1). Age, sex, comorbidity, rt-PA use, thrombectomy, interval between onset and final day of mRS score evaluation, and the proportion of patients with a good prognosis did not differ significantly between the HEMS and GEMS groups.

Four patients were transferred from rural medical services and 57 directly from the site of onset by HEMS. The interval between the emergency call and reaching our

hospital and the distance transported were significantly longer in the HEMS than the GEMS group; however, the interval between onset and reaching our hospital did not differ significantly between the groups. Large-artery atherosclerosis was more common in the GEMS than the HEMS group, whereas cardioembolism was more common in the HEMS than the GEMS group. Median NIHSS score, mortality, and median final mRS score were significantly higher in the HEMS than the GEMS group. A logistic regression analysis revealed that age ≥ 76 years, NIHSS score ≥ 7 , and acute treatment were significant predictors of a good prognosis (Table 2). The model likelihood ratio test showed $\chi^2 = 213.1247$, $P < .01$, and the result of the Hosmer-Lemeshow test was not significant ($P = .22$), indicating a good prediction model.

Discussion

The present study showed that, in rural Japan, patients transported by HEMS tended to have more severe cerebral infarction than those transported by GEMS. Functional outcomes were better with GEMS than HEMS;

Table 1. Characteristics of patients according to mode of transport

	Total n = 546	HEMS n = 61	GEMS n = 485	P value
Age, years	76 [68–83]	78 [67–84]	75 [68–83]	NS
Male, n (%)	323 (59.2)	36 (59.0)	287 (59.2)	NS
Hypertension, n (%)	228 (41.8)	25 (41.0)	203 (41.9)	NS
Diabetes mellitus, n (%)	86 (15.8)	6 (9.8)	80 (16.5)	NS
Dyslipidemia, n (%)	48 (8.8)	2 (3.3)	46 (9.5)	NS
Heart failure, n (%)	23 (4.2)	5 (8.2)	18 (3.7)	NS
Ischemic heart disease, n (%)	28 (5.1)	2 (3.3)	26 (5.4)	NS
Atrial fibrillation, n (%)	69 (12.6)	9 (14.8)	60 (12.4)	NS
Prior stroke, n (%)	86 (15.8)	10 (16.4)	76 (15.7)	NS
Current smoker, n (%)	124 (22.7)	9 (14.8)	115 (23.7)	NS
Time from emergency call to visit, min	35 [28–45]	61 [51–67]	33 [28–41]	<.01
Transport distance, km	6.5 [2.9–10.8]	41 [21.6–58.5]	5.3 [2.9–8.4]	<.01
Time from onset to visit, min	352 [100–1020]	255 [90–890]	360 [100–1020]	NS
Initial NIHSS, points	7 [3–16]	13 [4–19]	7 [3–16]	<.05
Stroke type, n (%)				
Large-artery atherosclerosis	123 (22.5)	7 (11.5)	115 (23.9)	<.05
Cardioembolism	248 (45.4)	35 (57.4)	213 (43.9)	<.05
Small-vessel occlusion	90 (16.5)	8 (13.1)	82 (16.9)	NS
Other determined etiology	17 (3.1)	2 (3.3)	15 (3.1)	NS
Undetermined etiology	68 (12.5)	9 (14.8)	59 (12.2)	NS
rt-PA, n (%)	54 (9.9)	9 (14.8)	45 (9.3)	NS
Endovascular therapy, n (%)	5 (9)	1 (1.6)	4 (.8)	NS
Final evaluation day of mRS	66 [16–132]	66 [12–145]	66 [16–130]	NS
Final mRS	3 [1–5]	4 [1–5]	3 [1–5]	<.05
Good outcome (%)	258 (47.3)	22 (36.1)	236 (48.7)	NS
Death, n (%)	63 (11.5)	12 (19)	49 (10.1)	<.05

Abbreviations: HEMS: helicopter emergency medical services; GEMS: ground emergency medical services; NIHSS: National Institutes of Health Stroke Scale.

Data are presented as the median [interquartile range]. P values were calculated using Fisher's exact test or the χ^2 test depending on the expected frequency for categorical variables, and the Mann-Whitney U test for continuous variables. $P < .05$ was considered to denote statistical significance. Values in bold indicate a significant difference between HEMS and GEMS.

Table 2. Logistic regression analysis for good prognosis in patients with cerebral infarction

Factors	n	OR (95% CI)	P value	OR (95% CI)	P value
		Unadjusted	Unadjusted	Multivariate model	Multivariate model
Age ≥ 76 years		.24 (.17-.34)	<.01	.31 (.20-.47)	<.01
Age $\geq 76 / < 76$	274/272				
Sex (male)		.59 (.42-.83)	<.01	–	–
Male/female	323/223				
HEMS		.60 (.34-1.03)	.065	–	–
HEMS/GEMS	61/485				
Comorbidity		1.05 (.73-1.51)	.79	–	–
Yes/No	378/168				
NIHSS ≥ 7		.086 (.058-.13)	<.01	.079 (.050-.12)	<.01
NIHSS $\geq 7 / < 7$	292/254				
Acute treatment		.89 (.51-1.55)	.68	2.63 (1.36-5.08)	<.01
Yes/no	56/490				

Abbreviations: OR, odds ratio; CI, confidence interval; NIHSS, National Institutes of Health Stroke Scale; HEMS, helicopter emergency medical services; GEMS: ground emergency medical services.

We adjusted for the following variables: age ≥ 76 years, sex, HEMS, comorbidity, NIHSS score on admission ≥ 7 , and acute treatment.

however, the transport system was not associated with prognosis. Age ≥ 76 years, NIHSS score ≥ 7 , and acute treatment were predictors of prognosis in patients with cerebral infarction.

Silliman et al reported that HEMS enabled an average transport distance of 29.5 miles in an average of 135 minutes and contributed to access to thrombolytic therapy in patients with cerebral infarction in a rural area of the USA.⁴ A prospective observational study showed that HEMS was not correlated with decreased mortality or disability, and that labor market participation was not better than with GEMS.¹² In our study, although interval between emergency call and reaching hospital and distance transported were significantly longer in the HEMS than the GEMS group, there was no significant difference in the frequency of acute treatment and interval between onset and reaching hospital. We found that the median distance transported was 41 km (25.5 miles) in a median of 61 min for HEMS, whereas for GEMS the median distance transported was 5.3 km (3.3 miles) in a median of 33 min. These results suggest that HEMS may shorten the transport time for patients who live in rural areas. However, functional outcomes and mortality were not superior in patients transported by helicopter. Given that the HEMS group had higher NIHSS scores than the GEMS group, one possible explanation for these findings is that patients transported by helicopter had more severe neurological symptoms. Another explanation for the similar prognosis between HEMS and GEMS could be the rate of treatments received; previous studies have reported that 24%-38%^{4,5} and 27%¹³ of patients transported by helicopter received thrombolysis and endovascular therapy, respectively; whereas, in our study, 16.4% of the 61 patients transported by helicopter received rt-PA or endovascular therapy. Logistic regression indicated that acute treatment had a positive effect on prognosis; thus, it is possible that the low frequency of acute treatment in

our study may have negatively impacted the overall prognosis of patients in the HEMS group.

This study had several limitations. First, we could not compare uniform distances between the HEMS and GEMS groups because ambulance transportation from rural areas currently rarely occurs in Japan. To account for this, we compared the groups using multivariate analysis. Second, although the final time of evaluating mRS scores did not differ significantly between the groups, we were unable to uniformly evaluate mRS 90 days after onset because of constraints related to the Aomori medical care zone system. Third, this was a retrospective study in a single tertiary center. Selection bias and information bias may have been present because the frequency of acute treatment for cerebral infarction was low and neurological symptoms were more severe in the HEMS than the GEMS group. Further prospective studies are necessary to clarify the association between HEMS and functional outcomes in rural Japan.

Conclusions

In our study in rural Japan, patients transported by HEMS had more severe stroke symptoms than those transported by GEMS, which may explain the poorer functional outcomes in the HEMS group. However, the transport time was shorter for HEMS, whereas interval between onset and reaching hospital was similar between GEMS and HEMS. Our results suggest that HEMS may be useful in reducing transport times for patients in rural Japan.

Acknowledgments

The authors would like to thank the medical staff of our department at Aomori Prefectural Central Hospital for providing the patients' care. We wish to thank Jane Charbonneau, DVM, and Trish Reynolds, MBBS, MRACP, from Edanz Group (www.edanzediting.com/ac) for editing a draft of this manuscript.

Conflicts of Interest

None declared.

References

1. Powers WJ, Rabinstein AA, Ackerson T, et al. 2018 Guidelines for the early management of patients with acute ischemic stroke: a guideline for healthcare professionals from the American Heart Association/American Stroke Association. *Stroke* 2018;49:e46-e110.
2. Mommsen P, Bradt N, Zeckey C, et al. Comparison of helicopter and ground emergency medical service: a retrospective analysis of a German rescue helicopter base. *Technol Healthc* 2012;20:49-56.
3. Hesselfeldt R, Gyllenborg J, Steinmetz J, et al. Is air transport of stroke patients faster than ground transport? A prospective controlled observational study. *Emerg Med J* 2014;31:268-272.
4. Silliman SL, Quinn B, Huggett V, et al. Use of a field-to-stroke center helicopter transport program to extend thrombolytic therapy to rural residents. *Stroke* 2003;34:729-733.
5. Reiner-Deitemyer V, Teuschl Y, Matz K, et al. Helicopter transport of stroke patients and its influence on thrombolysis rates: data from the Austrian Stroke Unit Registry. *Stroke* 2011;42:1295-1300.
6. Silbergleit R, Scott PA, Lowell MJ, et al. Cost-effectiveness of helicopter transport of stroke patients for thrombolysis. *Acad Emerg Med* 2003;10:966-972.
7. Kwan J, Hand P, Sandercock P. Improving the efficiency of delivery of thrombolysis for acute stroke: a systematic review. *QJM* 2004;97:273-279.
8. Matsumoto H, Mashiko K, Hara Y, et al. Effectiveness of a "doctor-helicopter" system in Japan. *Israel Med Assoc J* 2006;8:8-11.
9. Abe T, Takahashi O, Saitoh D, et al. Association between helicopter with physician versus ground emergency medical services and survival of adults with major trauma in Japan. *Crit Care* 2014;18:R146.
10. Adams Jr. HP, Bendixen BH, Kappelle LJ, et al. Classification of subtype of acute ischemic stroke. Definitions for use in a multicenter clinical trial. TOAST. Trial of Org 10172 in Acute Stroke Treatment. *Stroke* 1993;24:35-41.
11. Banks JL, Marotta CA. Outcomes validity and reliability of the modified Rankin scale: implications for stroke clinical trials: a literature review and synthesis. *Stroke* 2007;38:1091-1096.
12. Funder KS, Rasmussen LS, Lohse N, et al. The impact of a physician-staffed helicopter on outcome in patients admitted to a stroke unit: a prospective observational study. *Scand J Trauma Resusc Emerg Med* 2017;25:18.
13. Regenhardt RW, Mecca AP, Flavin SA, et al. Delays in the air or ground transfer of patients for endovascular thrombectomy. *Stroke* 2018;49:1419-1425.