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Original Research

The Impact of Air Transport for Acute Coronary Syndrome Patients

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A B S T R A C T

Objective: For patients with acute coronary syndrome (ACS), percutaneous coronary intervention (PCI) within 120 minutes from onset is recommended. A helicopter emergency medical service (HEMS) is useful for transporting ACS patients. The purposes of this study were to investigate whether patients with ACS in the eastern part of Hokkaido could be transported to a PCI hospital by HEMS and undergo PCI within 120 minutes and to clarify the factors most related to delayed access to PCI.

Methods: This was a retrospective cohort study that analyzed 513 patients diagnosed with ACS at our institution, an HEMS base/PCI hospital. We investigated transport modes for each patient and identified the processes by which access to PCI was delayed.

Results: HEMS reduced transport time compared with ground emergency medical services but did not contribute to access to PCI within 120 minutes. The most important factor was transport directly to a PCI hospital ($P < .01$).

Conclusion: HEMS did not achieve a total transport time of patients to a PCI hospital within 120 minutes from onset. Transport using HEMS is insufficient to access early PCI; patient condition must also be considered to determine whether to go through a non-PCI hospital.

Acute coronary syndrome (ACS) requires cardiac catheter treatment, such as percutaneous coronary intervention (PCI), for reperfusion of culprit coronary vessels as soon as possible.[1,2] According to the 2013 American College of Cardiology Foundation/American Heart Association guideline for the management of ST elevation myocardial infarction,[3] the recommended onset-to-balloon time (OBT) is within 120 minutes. To achieve this goal, patients need to be transported to a hospital where PCI can be performed (PCI hospital) as soon as possible.

Some reports have shown the usefulness of a helicopter emergency medical service (HEMS) as a transportation system to shorten OBT in cases when the PCI hospital is far from the onset point or when the condition of the patient is severe.[4-8] However, factors related to the usefulness of HEMS include regional circumstances including the size and distribution of the population, the location of the HEMS base hospital, the number of ground ambulances, emergency medical service (EMS) centers where ground ambulances are on standby, functions of receiving hospitals, the distance between the onset point and the hospital, road conditions, and others.[9,10]

Hokkaido island is located in the northern part of Japan and has a large area of 83,424 km^2 with a population of about 5.3 million people. HEMS was first introduced to Hokkaido in 2009,[11] but no reports have shown the efficacy of HEMS in cases with ACS for achieving access to PCI within 120 minutes, taking into consideration the regional circumstances of Hokkaido in Japan. The purposes of this study were to investigate whether HEMS in the eastern part of Hokkaido contributed to OBT within 120 minutes in patients with ACS and to clarify factors related to delays.

Methods

Patient Population

This was a single-center, retrospective, cohort study. After obtaining ethical approval for this study (no. 282-184) from the ethics committee at our institution, a retrospective electronic chart

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review of Kushiro City General Hospital (the HEMS base hospital/PCI hospital) and the records of each EMS center was performed from January 1, 2014, to December 31, 2016. The reasons why this area was chosen are described in Appendix 1. Briefly, this area is relatively isolated and has 2 PCI centers, both in Kushiro city, the central city of this area.

A total of 513 adult patients transferred to Kushiro City General Hospital with a diagnosis of ACS or acute myocardial infarction were registered to this study. The following data were collected: age, sex, and severity of ACS. Severe cases were regarded as those cases also showing cardiogenic shock that needed artificial respiration, extracorporeal membrane oxygenation, intra-aortic balloon pumping, and/or coronary artery bypass grafting.[12,13]

Definitions of Distance

Onset scenes were divided into 21 jurisdictions (areas 01-21) of EMS centers. Driving distances from the onset scene to a non-PCI hospital, a rendezvous point (RP), and a PCI hospital were calculated from the Google Maps website (https://www.google.co.jp/maps/, January 1, 2017).

Definitions of Transport Time

Ground ambulance staff or a doctor at a non-PCI hospital judged whether HEMS was necessary. Transport situations were divided into the following 5 patterns according to transport route and mode (Fig. 1). OBT was divided into 9 points, and the time for each step in the process was analyzed (Fig. 1).

Statistical Analysis

Patients who arrived at a PCI hospital directly by themselves and did not receive PCI were excluded. The chi-square test was used to evaluate independent predictors of outcome. The objective variable was access to PCI within 120 minutes, with explanatory variables of age, sex, transfer via a non-PCI hospital (present/absent), HEMS (present/absent), and severity of disease. Furthermore, to evaluate independent factors affecting access to PCI within 120 minutes since onset, multivariate logistic regression models were constructed. Odds ratios and 95% confidence intervals were calculated.

Those parts of the transport process that had the most influence were also examined. This analysis was performed to identify which stage took the longest time in transport from the onset scene to the PCI hospital. In areas 01 to 05 (distance between ambulance standby position and PCI hospital < 30 km), HEMS was not used during this study. Thus, the 243 cases in areas 01 to 05 were excluded, and only the 111 cases in areas 06 to 21 (distance between ambulance standby position and PCI hospital ≥ 30 km) for which HEMS and ground emergency medical service (GEMS) were used were included in the analysis. Patients were excluded if they arrived at a PCI hospital directly by themselves. However, patients who did not receive PCI were included in this study to consider which parts of the time course of transport to the PCI hospital were important. Factors related to achieving access to PCI within 120 minutes after onset of ACS were verified by the chi-square test. The corresponding part of the time course was compared using the Mann-Whitney *U* test. *P* values < .05 were considered significant.

Results

The eastern part of Hokkaido is divided into 21 areas according to EMS jurisdiction. The median distance between the EMS center and a PCI hospital was 48.4 km (interquartile range = 31.6-78.9 km). From January 1, 2014, to December 31, 2016, a total of 513 adult patients were transferred to Kushiro City General Hospital with a diagnosis of ACS or acute myocardial infarction. Among these, 354 patients were transported by EMS, and 159 patients arrived at the PCI hospital by themselves without using EMS.

Factors Affecting the Time to Access PCI Within 120 Minutes From Onset

Patients who arrived at a PCI hospital by themselves (walk-in: n = 159) were excluded from this analysis because the time of onset was unclear. Among the remaining patients (n = 354) transported by EMS, 229 patients underwent PCI, and 125 did not. Patients who were transported by EMS and underwent emergency PCI were analyzed.

Patient characteristics are shown in Table 1. PCI was accessed within 120 minutes from onset in 44 patients and beyond 120 minutes in 185 patients. Age and sex were comparable between the 2 groups. For patients with lower severity and a shorter transport

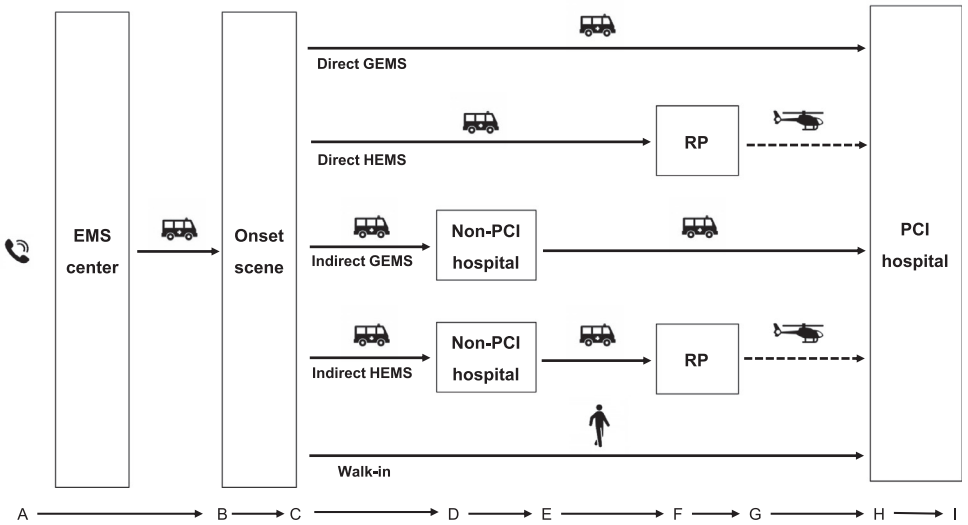

Figure 1. Time interval definitions from the emergency call to reperfusion achievement. A, emergency call; B, ground ambulance (GA) meets patient at onset scene; C, GA leaves onset scene; D, GA arrives at non-PCI hospital; E, GA leaves non-PCI hospital; F, GA arrives at RP; G, helicopter leaves from RP; H, helicopter arrives at PCI hospital; and I, PCI. Direct GEMS = transport directly from onset scene to PCI hospital by GEMS; direct HEMS = transport directly from onset scene to PCI hospital by HEMS (via RP by GEMS); indirect GEMS = transport from onset scene to PCI hospital via non-PCI hospital by GEMS; indirect HEMS = transport from onset scene to non-PCI hospital by GEMS and from non-PCI hospital to PCI hospital by HEMS (via RP by GEMS); walk-in = patient arrived at PCI hospital directly.

Table 1
Patient Characteristics and the Effects of Distance, Transport Route, and Time

	OBT < 120 min (n = 44)	OBT ≥ 120 min (n = 185)	*P* Value
Age (y)	65.5 (58-74)	71.0 (59-79)	.10
Male (n)	30 (68.2)	142 (76.8)	.24
Severity of patient condition (n)			
Severe	9 (20.5)	72 (38.9)	.03
Not severe	35 (79.5)	113 (61.1)	
Distance (km)	4.0 (3.2-5.9)	11.5 (4.0-75.6)	<.01
Transport route (n)			
Direct	44 (100)	158 (85.4)	<.01
Indirect	0 (0)	27 (14.6)	
Transport mode (n)			
GEMS	43 (97.7)	160 (86.5)	.04
HEMS	1 (2.3)	25 (13.5)	
Time from onset to PCI hospital (min)	27 (24-32)	47 (31-89)	<.01
30-day mortality (n)			
Survived	44 (100)	165 (89.2)	.02
Died	0 (0)	20 (10.8)	

GEMS = ground emergency medical service; HEMS = helicopter emergency medical service; OBT = onset-to-balloon time; PCI = percutaneous coronary intervention.
Data are presented as number (percentage) or median (interquartile range) and were analyzed using the Mann-Whitney *U* test.

distance, OBT was within 120 minutes ($P = .03$ and $P < .01$, respectively). The use of a direct transport route and transport by GEMS were also significantly associated with OBT within 120 minutes ($P < .01$ and $P = .04$, respectively).

Univariate (chi-square regression) analysis (Table 2) revealed significant differences in explanatory variables, including transport route (indirect) ($P < .01$), transport mode (HEMS) ($P = .04$), and severity of patient condition ($P = .03$), but these explanatory variables did not affect access to PCI within 120 minutes. In other words, if severe patients were transported by HEMS via a non-PCI hospital, as required by the guidelines, they would not access PCI within 120 minutes.

After calculating the rough odds ratios, including transport route (indirect), transport mode (HEMS), and severity of patient condition, no significant differences were identified on multivariate analysis. Using this analysis, no independent predictors of PCI access within 120 minutes could be identified.

Processes Influencing Delayed Arrival at PCI Hospitals for Each Transport Mode

As done in the former analysis, patients who arrived at a PCI hospital by themselves (walk-in: n =159) were excluded from this analysis. Among the remaining patients (n = 354), in areas 01 to 05 (distance between ambulance standby position and PCI hospital < 30 km), HEMS was not used. There are 2 reasons for this. The first is that this area is the center of the city, where a suitable ground transport network is maintained. The second is because housing density is high and an RP is difficult to secure. Thus, the 243 cases in areas 01 to 05 were excluded, and the 111 cases in areas 06 to 21 in which HEMS was used (distance between ambulance standby position and PCI hospital ≥ 30 km) were investigated (Fig. 2).

Table 2
Chi-square Regression Analysis

	P Value
Transport route (indirect)	<.01
Transport mode (HEMS)	.04
Severity of patient condition	.03

HEMS = helicopter emergency medical service.

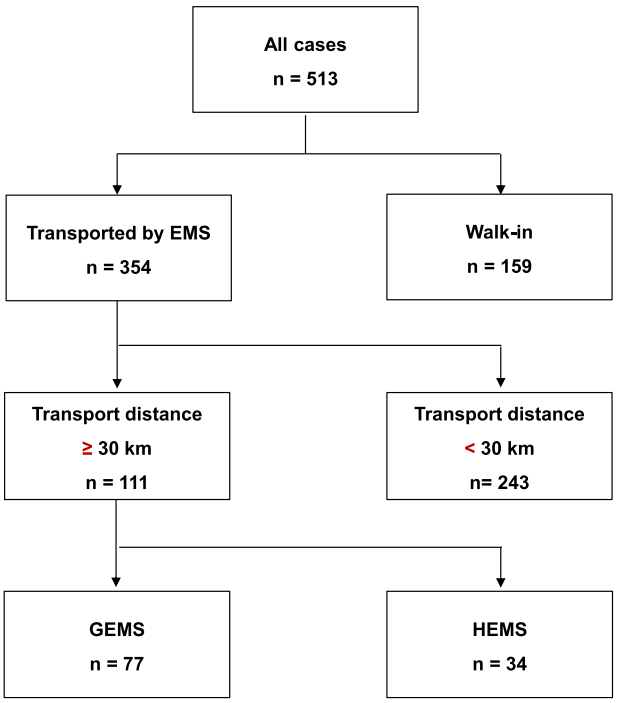

Figure 2. A flowchart of the patients included in the study.

Patient characteristics are shown in Table 3. The median distance between each emergency service and a PCI hospital was greater in the HEMS group than in the GEMS group ($P < .01$), and the mode of transport route (direct/indirect) was comparable. The severity of patient condition was higher in the HEMS group (50%) than in the GEMS group (28%, $P = .03$). The transport time from onset to a PCI hospital was significantly shorter in the HEMS group (81 minutes) than in the GEMS group (100 minutes, $P < .01$). Among these patients, for those who underwent PCI, the median OBT was significantly shorter in the HEMS group (168 minutes, n = 26) than in the GEMS group (201 minutes, n = 51, $P = .01$).

Figure 3 shows the distribution of the median time intervals based on transport route (direct/indirect) and mode (HEMS/GEMS). In the direct transport situation, transport time from the onset scene to a PCI hospital was comparable between GEMS and HEMS. The transport time from the emergency call to the arrival of the ambulance (A-B)

Table 3
Patient Characteristics and Effects of Distance, Transport Route, and Time

	GEMS (n = 77)	HEMS (n = 34)	*P* Value
Age (y)	66 (55-78)	76 (70-83)	.01
Male	53 (69)	26 (77)	.50
Severity of patient condition			
Severe	22 (29)	17 (50)	.03
Not severe	55 (71)	17 (50)	
Distance (km)	90.7 (48.4-93.4)	92.1 (75.6-93.4)	<.01
Transport route			
Direct	55 (71)	24 (71)	1.00
Indirect	22 (29)	10 (29)	
Transport time (min)			
Time from onset to PCI hospital door	100 (65-150)	81 (71-103)	<.001

GEMS = ground emergency medical service; HEMS = helicopter emergency medical service; OBT = onset-to-balloon time; PCI = percutaneous coronary intervention.
Data are presented as number (percentage) or median (IQR).

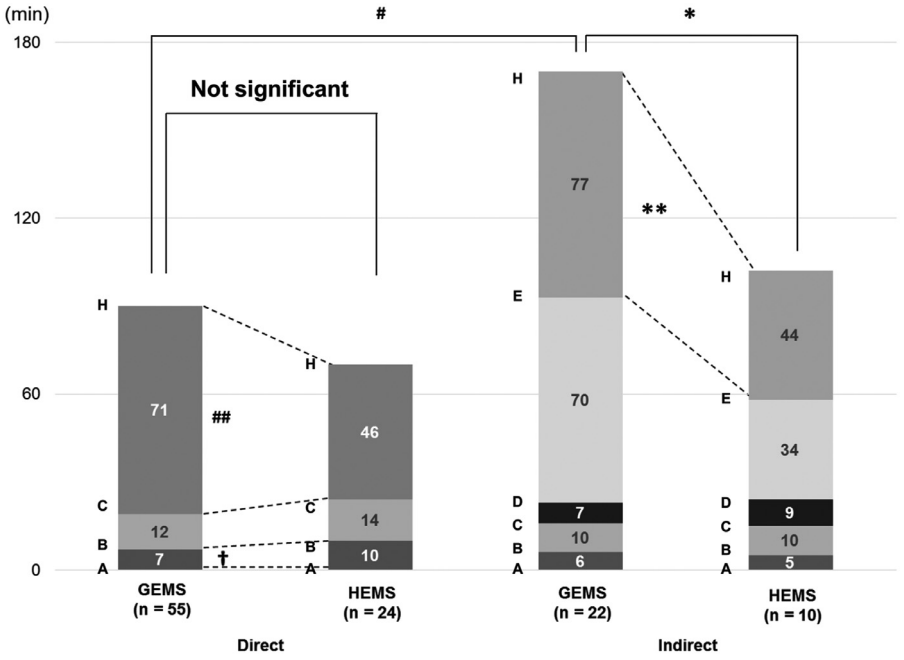

Figure 3. The distribution of median time intervals based on the mode of transport route and mode. Direct = transport directly from onset scene to PCI hospital; indirect = transport from onset scene to PCI hospital via non-PCI hospital; NS = . A, emergency call; B, GA meets patient at onset scene; C, GA leaves from non-PCI hospital; D, GA arrives at non-PCI hospital; E, GA leaves from non-PCI hospital; and H, helicopter arrives at PCI hospital. *$P < .05$ versus HEMS group in the indirect group (A-H; ie, from onset to PCI). **$P < .05$ versus HEMS group in the indirect group (E-H; ie, from non-PCI to PCI hospital). #$P < .05$ versus GEMS group in the direct group (A-H; ie, from onset to PCI). †$P < .05$ versus HEMS group in the direct group (A-B; ie, from onset to meeting patient). ##$P < .05$ versus HEMS group in the direct group (C-H; ie, from onset scene to PCI hospital).

was significantly shorter in the GEMS group than in the HEMS group ($P < .05$), and the time from departure from the onset scene to arrival at a PCI hospital (C-H) was significantly greater in the GEMS group than in the HEMS group ($P < .05$). In the indirect transport situation (ie, stop off at a non-PCI hospital on the way to a PCI hospital), the transport time from the onset scene to a PCI hospital was significantly shorter in the HEMS group than in the GEMS group ($P < .05$). The time from a non-PCI hospital to a PCI hospital (E-H) was significantly longer in the GEMS group than in the HEMS group ($P < .05$). The time spent in a non-PCI hospital (D-E) in the indirect groups was comparable between the GEMS and HEMS groups. The time from onset to arrival at a PCI hospital by direct GEMS was significantly shorter than that by indirect GEMS ($P < .05$) but was comparable between direct and indirect HEMS.

Discussion

This study showed that HEMS in the eastern area of Hokkaido in Japan shortened the time to transport ACS patients from the onset scene to a PCI hospital compared with GEMS. However, HEMS did not contribute to achieving the guideline-recommended goal[3] of emergency PCI performed within 120 minutes since onset. In the present study, the 30-day mortality rate was significantly lower in the OBT < 120-minute group (0/44, 0%) than in the OBT > 120-minute group (20/185, 10.8%, $P = .02$). This result has confirmed the usefulness of the guideline.[3] Thus, patients need to be transported to a PCI hospital as soon as possible.

Multivariate analysis was performed to clarify predictors of OBT < 120 minutes, but no independent factor was identified. On univariate analysis, HEMS was a factor associated with not achieving OBT < 120 minutes. The reason for this was that 43 of 44 patients who achieved OBT < 120 minutes were transported by GEMS. In the study area, 2 PCI hospitals are located in an urban area, which has a large population and a large number of cases. The onset scene for most cases achieving OBT < 120 minutes was close to the PCI hospital; therefore, HEMS was not used.

The most significant factor for not achieving OBT < 120 minutes was transport via non-PCI hospitals on the way. Stops may be made at a non-PCI hospital on the way to a PCI hospital for various reasons. First, there is the possibility that GEMS staff may not recognize the necessity for transport to a PCI hospital. Second, if the patient had been in a severe condition and the onset scene was far from a PCI hospital, the GEMS staff might have determined that transport to a nearby non-PCI hospital would be preferable to obtain initial treatment before transport directly to a PCI hospital. The need to conduct various investigations at the initial examination and the lack of staff in non-PCI hospitals in more rural areas may lead to extended stays at non-PCI hospitals. However, this study did not carefully consider the detailed processes in ground ambulances or non-PCI hospitals before arriving at the PCI hospital.

The transportation system in Japan could have resulted in delays for patients needing PCI appropriately.[13] In Japan, GEMS staff are emergency medical technicians, not doctors. They must select a suitable hospital based on the severity of the patient's condition or based on guidance from doctors working at a distance. Therefore, in the near future, it will be necessary to construct a system that can transmit the electrocardiogram waveform to doctors in PCI hospitals at the time GEMS staff first reach the patient so that ACS patients can be transported directly and rapidly to appropriate hospitals.[14,15]

The area of Hokkaido is wide; only 2 hospitals in the eastern area can perform PCI, and both are located in the central city of Kushiro. HEMS was useful for transporting patients from a far distant onset scene. Several studies have shown that HEMS is significantly faster than GEMS for transporting patients from a distance.[5-7] In the present study, HEMS shortened the time to transport ACS patients from the onset scene to a PCI hospital compared with GEMS. However, for patients with life-threatening conditions such as ACS, even for those with a severe condition, the use of HEMS is insufficient. The median time from PCI hospital arrival to reperfusion was 100 minutes (interquartile range, 83-122 minutes). To achieve the goal of OBT < 120

minutes, efforts to shorten the time from onset to PCI are also necessary, such as by avoiding stops at non-PCI hospitals.

Some limitations to this study must be considered. First, it could not be shown that all ACS patients in this area during the research period came to the PCI hospital (Kushiro City General Hospital). This was because patients in this study were diagnosed as having ACS or acute myocardial infarction at the PCI hospital, and severe cases, such as patients with cardiac arrest or shock, may have died at a non-PCI hospital rather than being transported to a PCI hospital. The area of Hokkaido prefecture is large, and only 2 PCI hospitals are present in eastern Hokkaido, with both being located in the central city of Kushiro. Conversely, this area is surrounded by sea and high mountains, and most ACS patients come to the central city (ie, analysis of PCI situations in this study could show high reliability and impact with respect to other areas in Japan as well as in other countries).[4,8,9]

Second, road/weather conditions and the RP situation were not considered in the present study. Furthermore, the distance between the EMS center and the PCI hospital was used as the transport distance and thus did not represent the exact transport distance. In addition, this region is cold in winter, although snow is rare, and foggy in summer when HEMS cannot be used.

Third, HEMS was shown to transport patients with severe ACS from a distance to a PCI hospital faster than GEMS. Some studies have shown that HEMS improved the prognosis of ACS patients,[5,16] but others have not.[17,18] This is a controversial theme that has not yet been decided. In the present study, inpatient hospital expenses were analyzed, but the costs of GEMS and HEMS were not considered. Clarifying the cost of GEMS in each EMS center would be difficult. Although HEMS has developed rapidly in Japan,[19] continuous examination of the usefulness of HEMS for ACS patients is needed to operate HEMS effectively in Japan.

In conclusion, HEMS in the eastern area of Hokkaido was properly applied but did not shorten the total transport time of ACS patients to a PCI hospital to within 120 minutes from onset. To achieve earlier access to PCI, transport using HEMS is insufficient. Permitting the EMS to decide whether to go through a non-PCI hospital and training them to recognize the need for early transfer by a non-PCI hospital is also important, considering the condition of the individual patient.

Appendix 1. Characteristics of the area and transport in this study

A. Characteristics of Hokkaido Island and the Eastern Area of Hokkaido (Senkon Area)

In Hokkaido, the jurisdiction of the HEMS can be divided into 4 parts (east, north, south, and central). In the area of eastern Hokkaido, the HEMS covers an area of 9,496 km^2 with a population of 0.33 million, with 0.18 million of those inhabitants living in Kushiro, which is the site of the HEMS base facility and 1 of 2 PCI hospitals in Kushiro City, the central city of eastern Hokkaido. In the area of eastern Hokkaido, the ambulance service area is divided into 21 sections. The distance from each EMS center to the PCI hospital, area, and population data obtained from each EMS center home page (as of April 1, 2017).[20] As a rule, the area of jurisdiction close to Kushiro City is narrow, and the population is large; the area of jurisdiction far from Kushiro City is wider, and the population is smaller. Furthermore, HEMS operates only during the daytime because visual flight rules are in effect.

B. Outline of HEMS in Japan[21,22,23]

Direct transport: a helicopter is usually on standby at the HEMS base hospital. When a patient (or discoverer) calls for emergency services, the call is directed to the nearest EMS center where the ground ambulance is on standby. If the degree of emergency or the severity of the condition is judged as high, EMS staff at the onset scene contact the HEMS base via the EMS center and request HEMS. A ground ambulance and a helicopter meet at an RP where the helicopter can take off and land immediately. HEMS medical staff (1 doctor and 1 nurse) reach the patient in the ambulance and immediately go to the destination facility by helicopter.

Indirect transport: if the patient is transported to a non-PCI hospital and PCI is determined to be necessary, the doctor of the non-PCI hospital calls the nearest EMS center. The EMS center then contacts the HEMS base to request HEMS, and a ground ambulance and a helicopter meet at an RP close to the non-PCI hospital to pick up the patient and bring the patient to the PCI hospital.

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