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Comparative Study on the Outcome of Trauma Patients Transferred by Doctor Helicopters and Ground Ambulance in South Korea

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Abstract

Objective: The purpose of this study was to analyze the cost-effectiveness of helicopter emergency medical services (HEMS) for its economic operations in South Korea.
Methods: This study targeted trauma patients that were transported by either HEMS or ground emergency medical services (GEMS) from the scene of an accident to a regional emergency medical center. From this patient population, severe trauma patients (injury severity score ISS $\geq$ 16 points) with a distance travelled from the scene of the injury to the hospital that was 30 km or longer and with analyzable outcome data were extracted and included in this study. Cost-effectiveness was analyzed from survival and efficiency based on medical costs incurred from the pre-hospital setting to hospital discharge. This study included a total of 34 HEMS and 105 GEMS patients with an Injury Severity Score (ISS) $\geq$ 16 points from a pool of 357 potential patients.
Results: The survival-to-discharge rate of HEMS was 29 of 34 patients (85.3%) and was significantly higher than that of GEMS, where only 66 of 105 patients (62.8%) survived to discharge ($P = 0.024$). The expected and the actual mortality was higher in HEMS than it was in GEMS. Statistical significant difference in cost was found between the 2 groups ($P = 0.002$).
Conclusions: The results of the present study indicate the increased discharge rate, survival rate and reduced in hospital mortality of HEMS with reduced admission time. This result association leads to reasonable cost effectiveness and efficient estimates overall.

Helicopter emergency medical services (HEMS) have been developed as a part of a system to improve the emergency medical services (EMS) and mortality of patients in developed countries. However, there has been considerable debate concerning the cost-effectiveness and efficiency of HEMS compared with ground emergency medical services (GEMS).[1] HEMS have been locally operated since 2011; however, the cost-effectiveness of HEMS has been questioned. According to several studies performed to investigate HEMS activity and its cost-effectiveness, HEMS has higher operating costs than GEMS. Additionally, certain economic levels and medical infrastructure are required to operate the HEMS.[2] The benefits of HEMS in comparison to GEMS are: first, it promotes rapid transport from the accident scene to the hospital for severe trauma patients[3] and second, it involves sending highly skilled and experienced health-care professionals to deliver advanced medical procedures for trauma patients from the scene, which significantly reduces mortality in patients.[4]

The effect of HEMS depends on the environment of emergency medical services (EMS). However, recent studies that have been conducted on the effects of HEMS in the EMS environment of Korea are insufficient to identify the cost-effectiveness of HEMS.[5] According to studies that have addressed the effects of HEMS abroad, EMS activities reduced the mortality of emergency patients.[6] Directly comparable variables should be used to measure the cost-effectiveness of HEMS; however, variables that are not directly comparable are attributed to economic status and medical environment in each country, which further contributes to differences between countries.[7] Nonetheless, systematically, HEMS has higher operating costs compared with GEMS; therefore, further studies are needed to analyze the cost-effectiveness of HEMS.

Reduced mortality as well as cost-effectiveness and efficiency are crucial factors in the future of HEMS.[8] So far, domestic studies have not determined the effectiveness of a 3+-y HEMS program. Therefore, the purpose of this study was to analyze the efficiency of HEMS and its cost-effectiveness.

Methods

Study Design and Population

This study examined a retrospective cohort to analyze the HEMS system activities and status to improve emergency medical service activities. This was performed from July 2013 to April 2014

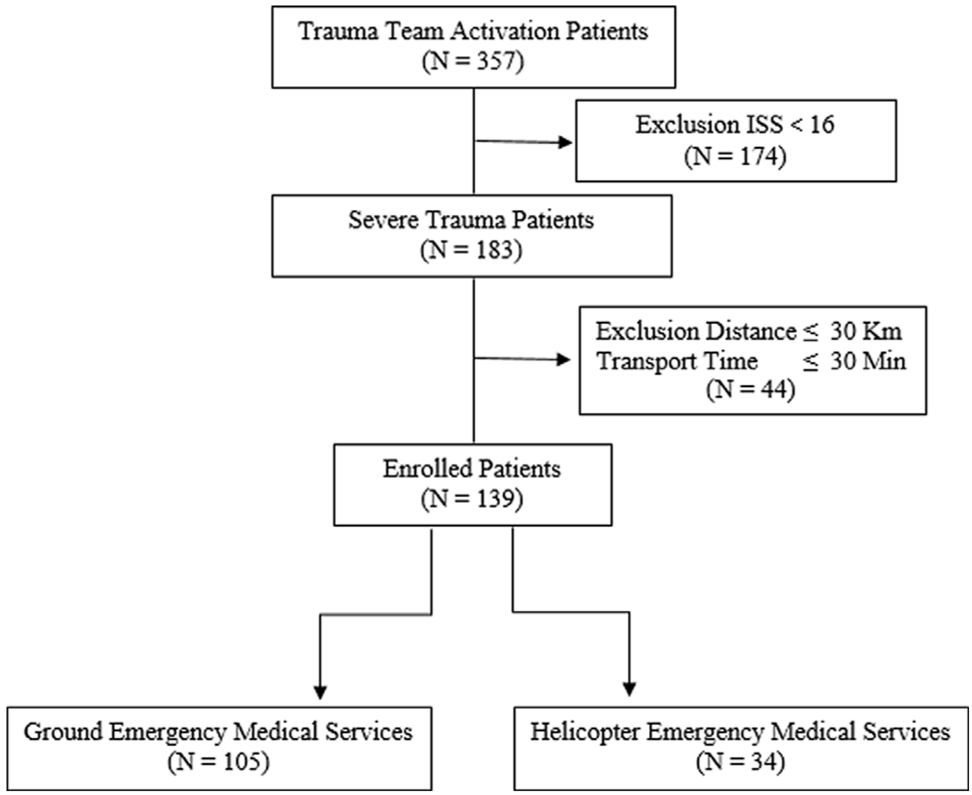

Figure 1. Scheme: The group of HEMS and the group of ground EMS are enrolled trauma patients. The scheme is included the decision of choosing HEMS as opposed to GEMS for the scene transport of an injured patient to a regional emergency medical center.

for approximately 10 mo in Gangwon, Korea. Among 183 trauma patients that were transferred to region emergency center during the study period, 34 severe trauma patients transported by HEMS and 105 trauma patients transported by GEMS were included in this study. Wonju Severance Christian Hospital, Yonsei University, is currently located in Wonju City and one of the best hospitals in central Korea with 850 beds and 29 clinical departments. The hospital is designated by Minister of Health & Welfare as a trauma center in the region in 2013 and began the capabilities of Level 1 trauma center in November 2014. All cases involved in the study involved injuries incurred at the accident scene and were referred from other hospitals to our hospital by HEMS or GEMS within an hour, without hospital admission or treatment (Figure 1).

Subjects and Model Validation

The following were used as inclusion criteria in this study: (1) Injury Severity Score (ISS) ≥ 16 points, (2) The distance travelled from the scene of injury to hospital was 30 km or longer, and (3) Analyzable outcome data were available. The following were used as exclusion criteria in this study: (1) ISS < 16 points, and (2) The distance traveled from the scene of injury to hospital was less than 30 km.

We collected data regarding severe trauma patients that were transported by HEMS and GEMS. Data from patients who were transported by HEMS during the study period were extracted from the Gangwon Aviation Operations Team records in the computer management system, and data from severe trauma patients that were transported by GEMS during the same period who were referred, treated and discharged from the Gangwon emergency center at our hospital were extracted from the Order Communication System and electronic medical records. Data extracted from the system included patient's Glasgow Coma Scale (GCS), ISS, Abbreviated Injury Scale (AIS) score, Revised Trauma Score (RTS), Trauma and Injury Severity Score (TRISS), Revised Trauma Score (RTS), and overall medical costs accrued before or at the hospital. The quality of life measurement (QLM) was also performed.

The estimated survival was determined by TRISS-based predicted mortality.[9] TRISS uses an equation to measure the patients' probability of survival (Ps) from ISS and RTS.[10] The survival benefit is drawn from the expected death (e) and the observed death (σ) to calculate the probability of survival during patient transfer and transport.

$$\text{Number of lives saved} = \frac{e}{n} * \left[1 - \frac{\delta}{n}\right] * 100$$

The following times were specified to investigate the effects of HEMS: (1) The time required to transport the patient from the scene of injury (location of accident) to the hospital, (2) The transport time from the scene (helicopter landing point) to hospital, and (3) The time patients spent waiting for surgery once they were admitted to hospital.

To investigate the patient's prognosis, survival to hospital discharge, mortality, and mortality within the first 24 h after hospital admission were analyzed to investigate the difference between the 2 groups. The treatment period at the hospital included the total period of hospital admission, length of stay in the intensive care unit, and length of stay in the general ward (GW).

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Cost Calculation

Calculation of medical costs was divided into 3 extractions to investigate efficiency. Costs were further classified into: (1) medical treatments and surgical procedures, (2) hospital admission and treatment, and (3) transportation costs before hospital admission. The patient record system at Wonju Severance Christian Hospital, Yonsei University, was used to analyze the duration of patients admitted to a hospital during the same period as the study period. The costs charged in all departments the patients were referred to during their hospital stay were extracted, which included the emergency department, intensive care unit, rehabilitation center, and all other departments related to treatment. A total of 6 patients were referred to other hospitals and were excluded from this study.

Currently, there is not a domestic standard for calculating medical costs before when a patient is admitted to a hospital; therefore, the guidelines for standard costs from each HEMS and GEMS administrator was used. GEMS was quoted as Korean Republic won (KRW) 200,000 for a 1-time dispatch and the cost included fuel, labor, and system operations, whereas HEMS was quoted as KRW 4,000,000 for a 1-time distich including fuel, labor, and system operations. After a patient was admitted to the hospital, all cost data, including examination, treatment, and surgical procedures, were extracted from the emergency admission department's cost management system to calculate the comprehensive medical treatment cost. The total costs, which included costs before admission and at the hospital, were used in this study. However, treatment and management costs after discharge were not included.

The incremental cost-effectiveness ratio, which was defined as the average cost of the emergency treatment strategy before admission to 2 different hospitals divided by the difference of the average health effects, was analyzed. The effects are presented as quality-adjusted life years (QALY). QALY is the measure of the value of life, combining mortality and non-fatal outcomes, including both quality and quantity of life lived. This requires combining fatal and nonfatal injuries. The incremental costs of HEMS comprise additional medical costs that were charged to treated patients compared with GEMS patients.[11]

$$\text{W-statistic } (\text{Number of observed deaths} - \text{Number of predicted deaths/N}) \times 100$$

$$\text{Z-statistic} = \frac{\text{Number of observed deaths} - \text{Number of predicted deaths}}{\sqrt{\sum(Ps(1-Ps)}}$$

Life expectancy refers to a statistical measure for the average number of years of life remaining at a given age. The mean life expectancy is determined by the number of the total of survivals at each age group divided by the number of survival. Life expectancy is estimated based on the mortality table from the World Health Organization (WHO), which is drawn from the mean age and gender of patients. The cost-effectiveness per survival is calculated considering the per capita gross national product (GNP).

Data Analysis

Because the subjects of the 2 study groups were not directly comparable due to difference in regions and resources, the average and standard deviation of costs before and after hospital admission were analyzed and compared, taking into consideration the N-value difference between the 2 groups. HEMS and GEMS patient data were used to analyze the following: The general status of patients was compared through basic statistical analysis. ISS, AIS, and RTS scores were measured when the patient was referred and the scores were compared. Next, the effects of HEMS activities were analyzed by comparing outcomes.

IBM SPSS version 20.0 (SPSS Inc, Chicago, IL) was used to perform the statistical tests. Chi-square tests were then performed on categorical variables, whereas continuous variables were analyzed using logistic regression and student t-tests. P values less than 0.05 were considered statistically significant.

Results

A total of 139 patients were included in this study. Thirty-four patients were transported by HEMS, whereas 105 patients were transported by GEMS. The mean age of the patients transported by HEMS was 52.4 ± 16.4, whereas the mean age of the patients transported by GEMS was 49.3 ± 20.3 ($P = 0.332$). The total number of hospitalization days was 27.1 ± 30.2 and 26.8 ± 30.9 in HEMS and GEMS, respectively ($P = 0.891$). The length of intensive care unit (ICU) stay was 7.1 ± 10.3 d in HEMS transport and 7.4 ± 12.9 d in GEMS transport. Length of stay in the GW was 20.0 ± 23.3 d in HEMS transport and 19.3 ± 24.5 d in GEMS transport. No significant difference was observed in total length of hospital stay between those who received treatment in the ICU ($P = 0.953$) and GW ($P = 0.921$). The transport time of patients by HEMS and GEMS from the scene to the hospital was 64.52 ± 28.7 and 73.75 ± 36.8 min, respectively. The time from transfer of patients from the scene to hospital admission was 149.58 ± 35.1 and 174.29 ± 33.6 min by HEMS and GEMS, respectively; no significant difference was found ($P = 0.612$). However, the time patients had to wait at the hospital for admission was 80 ± 12.4 min for HEMS and 240 ± 24.7 min for GEMS, indicating a significant difference ($P = 0.000$).

GCS, RTS, ISS, and TRISS were used to describe injury severity. The GCS is a 12-point scale that divides patients at the same level in the 2 groups. The mean RTS in HEMS and GEMS was 9.54 points and 8.91 points, respectively.

The mean ISS in this study was 21.97 ± 7.64 in HEMS and 22.85 ± 6.95 in GEMS ($P = 0.961$). The ratios of hospital discharge, mortality, and mortality that occurred within the first 24 h after admission were analyzed as outcomes of the 2 groups. The survival-to-discharge rate of HEMS (85.3%) was significantly higher than that of GEMS (62.8%) ($P = 0.024$).

Three patients transported by HEMS (8.8%) were found dead, whereas 23 of 105 patients transported by GEMS (21.9%) were found dead on admission ($P = 0.000$). A significantly lower mortality within the first 24 h after admission was observed in HEMS patients (5.9%) than in GEMS patients (15.2%) ($P = 0.022$; Table 1).

The average total medical cost before and after hospital admission in patients transported by HEMS was KRW 14,610 (10^3 won), whereas that of GEMS was 14,540 (10^3 won). No significant difference in cost was found between the 2 groups ($P = 0.978$). The survival rate, however, was higher in HEMS, 85.29% compared with 62.8% in GEMS ($P = 0.024$). The life expectancy among all of the study patients was 12.91 y per 100 cases with an average life expectancy of 19.17 y. Therefore, the cost-effectiveness per survival was estimated at KRW 369,220 (10^3 won) (Table 2).

The expected mortality was 19.22% in GEMS versus 11.36% in HEMS ($P = 0.002$). The actual mortality rate was 27.61% in GEMS versus 14.70% in HEMS ($P = 0.002$). The observed to expected

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Table 1. Characteristics of patients assisted by HEMS or GEMS

	HEMS	GEMS	*P*-Value
Patients (male)	34 (25)	105 (76)	–
Age (y; mean ± SD)	52.41 ± 16.40	49.25 ± 20.27	0.332
Length of hospital stay (days)	27.09 ± 30.24	26.78 ± 30.88	0.891
Intensive care unit (days)	7.12 ± 10.27	7.45 ± 12.91	0.953
GW (days)	19.97 ± 23.27	19.33 ± 24.52	0.921
Transportation time (min)	64.52 ± 28. 68	73.75 ± 36.75	0.594
Accident to GW admission (min)	149.58 ± 35.14	174.29 ± 33.56	0.612
Wait time for admission (min)	80 ± 12.36	240 ± 24.68	0.000
Injury severity			
GCS	12 ± 4	12 ± 4	0.967
RTS	9.54 ± 3.26	8.91 ± 4.01	0.983
ISS	21.97 ± 7.64	22.85 ± 6.95	0.961
TRISS	0.87 ± 0.24	0.81 ± 0.36	0.961
Outcome *N* (%)			
Discharge	29 (85.3)	66 (62.8)	0.024
Death	3 (8.8)	23 (21.9)	0.000
Death within 24 h	2 (5.9)	16 (15.2)	0.022

Abbreviations: GCS, Glasgow Coma Scale; RTS, Revised Trauma Score; HEMS, helicopter emergency medical services; GEMS, ground emergency medical services.
Note: Discharge indicates total number of discharged. Death indicates total number of deaths in hospital. Death within 24 h indicates total number of deaths within 24 h.

Table 2. Adjusted cost per life saved of HEMS or GEMS

	HEMS	GEMS	*P*-Value
Cost of hospitalization (10^3 won)	14,610	14,540	0.978
Survival rate (%)	85.29	62.8	0.024
Net lives saved per 100 transports (cases)	12.91		–
Mean life expectancy (y)	19.17		–
Cost per life saved (10^3 won)	369,220		–

Note: Cost of hospitalization indicates the average cost per hospital stay. Survival rate indicates the average rate of survival. Net lives saved per 100 transports indicates the net benefits = total benefits – total cost. Mean life expectancy indicates a statistical measure of how long a person may live. Cost per life saved indicates the amount per life saved.

Table 3. Survival probability of HEMS or GEMS

	HEMS	GEMS	*P*-Value
Expected mortality	11.36	19.22	0.002
Actual mortality	14.70	27.61	0.002
Estimated mortality	1.29	1.43	0.024

Note: Expected mortality indicates the ratio of observed deaths to expected deaths in the study group. Actual mortality indicates the ratio of actual mortality. Estimated mortality indicates the ratio of observed deaths to estimated deaths in the study group.

mortality (O/E) ratio was 1.43% in GEMS versus 1.29% in HEMS ($P = 0.024$) (Table 3).

The results indicated that HEMS was associated with higher costs than GEMS; however, the actual mortality of patients transported by HEMS was lower and HEMS had a higher survival rate. Therefore, HEMS is more effectives and efficient from a medical economics perspective on emergency medical services.

The total medical expense of survival in HEMS was higher than it was for GEMS; however, no statistically significant difference in cost was found between the 2 groups ($P = 0.978$). The analysis indicated that there were higher costs for HEMS compared with GEMS, which is likely attributable to higher initial costs required for medical care and physicians' aid on the helicopter.

Discussion

To date, there have not been any studies that have determined the cost-effectiveness of HEMS system since its introduction in 2011. Therefore, this study was performed to analyze the activities of the HEMS system in Korea to further investigate the cost-effectiveness of HEMS.

Institutions that provide EMS should continuously seek to improve efficiency and effectiveness for quality improvement of the system.[12] Effectiveness is determined by achieving optimal results, while efficiency is focused on achieving a goal at the earliest stage with the minimum investment. It is very important to define activities that are on-going or activities that have already been implemented to determine how to improve or create a new plan for more efficient and effective methods.[13]

Several studies have evaluated the cost-effectiveness of HEMS in some countries; however, currently, no guidelines have been proposed. According to a previous study that was performed by Gearhart in the United States, HEMS was effective for treating trauma patients. However, the study did not perform an incremental analysis of cost-effectiveness, which was a limitation.[14] In this study, the costs of HEMS were slightly higher than that of GEMS; however, the difference was not statistically significant.

HEMS systems have been adopted in developed countries, but there are a limited number of active studies on the effects. According to Brown et al., the HEMS transportation time is more accurate and rapid than GEMS.[15] In a study carried out by Park et al., HEMS was found to cover long distances and areas that are not accessible by GEMS for transporting emergency patients.[16] In this study, the HEMS transportation time was also found to be faster than GEMS, and HEMS transported patients to hospital able to perform a surgical operation. Emergency medicine physicians in prehospital settings performed procedures for patients and cared for and evaluated emergency patients from the scene of an accident; therefore, on average, patients were transported to an operating room within 80 min, without additional examination or wait time at a hospital. The results of a previous study performed by Duke and Clarke[17] indicated that the mortality of traumatized patients is determined within the first hour; therefore, the accurate and quick medical services provided by HEMS, followed by referral to surgery within 60 min in the Gangwon area, was considered a significant factor that reduced mortality. According to previous studies by Wigman et al.,[18] HEMS activities were effective for reducing patient mortality. The results of this study indicated that the mortality of severe trauma patients was less in the HEMS group than the GEMS group. However, despite these effects, the previous studies that propose the standard mythology to verify the economic effects of HEMS system are still insufficient. Additionally, there are no international standard guidelines for EMS and HEMS and scientific studies that discuss economic effects are also lacking.[19]

This study was limited in the ability to compare cost-effectiveness between different countries that are attributable to different economic circumstances and medical environments in each country. A definite and clear measurement index should be based

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on investment cost, consumption cost and treatment cost for a comprehensive cost-effectiveness study.[20]

Based on the results drawn from the aforementioned studies, the results of this study revealed that HEMS effectively reduced the mortality of severe trauma patients and the QALY value was slightly higher for HEMS patients. No significant difference was found in the total cost of HEMS and GEMS, and no significant difference was found in the QALY, compared with the results drawn from Ringburg et al.[21] It is possible that there was bias in the comparison between the actual patients transported by HEMS and GEMS[22]; however, symptoms of different injuries in patients, as well as non-standardized calculation of costs, were excluded.

A shorter overall transportation time, accurate diagnosis and on-site care, transportation to available hospitals, and specific, rapid and appropriate treatment at the hospital are factors that influence the prognosis and mortality of severe trauma patients in pre-hospital and hospital settings.[23] Shorter transportation time and professional on-site care in HEMS are more effective for reducing the mortality of severe trauma patients compared with GEMS.[24]

Patient prognosis was affected by transportation to the surgical hospital or trauma center.[25] In contrast, this study showed some differences in transportation, compared with previous studies. In this study, prompt response time of HEMS was not observed due to failure in cooperating with domestic institutes. Additionally, on-site care provided by emergency medicine physicians, including diagnosis, emergency treatment and medication, and HEMS transportation to a hospital that offered surgery and medical treatment were included in this study. HEMS was compared with GEMS under the same conditions. As mentioned previously, the effects on trauma patient mortality were significantly different. However, some studies have questioned whether the investment costs of HEMS are reasonable. As shown in the study results, the difference in cost is definite, but not significant.

Table 2 shows the results of this study, which suggest that there was no significant difference between the 2 groups in cost; however, we determined that HEMS was more effective in reducing mortality and had a higher survival rate. The survival rate was higher in HEMS, 85.29% compared with 72.38% in GEMS ($P = 0.02$). The efficiency and effectiveness of EMS is primarily focused on increasing patient survival rate.[26] This further suggests that HEMS is effective in reducing the mortality and increasing survival rate in patients; therefore, HEMS should be considered for future studies and implementation. To address the cost-effectiveness and efficiency of HEMS, the dispatch rate of HEMS should be increased for severe trauma patients that are transported long distances (>30 km). The patient should not be classified into severe or mild at the incidence site; therefore, the more HEMS operations are found to be more effective in reducing the mortality of severe trauma patients.[27] The analysis indicated that HEMS is more effective than GEMS; however, additional studies should be performed to confirm this cost-effectiveness analysis. Which will provide crucial information for decision making and policy implementation.[28] This information will also be valuable for evidence-based decisions to distribute system resources and determine policy priorities.[29]

GEMS was quoted as KRW 200,000 for a 1-time dispatch and the HEMS was quoted as KRW 4,000,000 for a 1-time distich including fuel, labor, and system operations. After a patient was admitted to the hospital, all cost data were extracted from hospital management system. The study results showed that HEMS was more costly than GEMS; however, because no standard has been established for the costs of HEMS and GEMS, additional follow-up studies that propose a definite standard for cost calculation, particularly for the operation of EMS systems, are needed to confirm the differences. Establishing a standard will allow the cost calculation between the 2 groups to be more clear.

Conclusions

The results of the present study indicate the increased discharge rate, survival rate, and reduced in hospital mortality of HEMS with reduced admission time. As short admission time have great clinical implications, outcome benefit of severe trauma patients transported by HEMS. This result association leads to reasonable cost-effectiveness and efficient estimates overall.

Conflicts of interest. Jeong Il Lee and Kang Hyun Lee declare that they have no conflict of interest.

Ethical standards. This study was approved by the institutional review board of Wonju Severance Christian Hospital, Yonsei University (YWMR-15-5-043). Informed consent was waived by the board.

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