

Time-saving effects using helicopter transportation: comparison to a ground transportation time predicted using a social navigation software

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Abstract

Previous comparison studies regarding 2 types of transportation, helicopter (HEMS) versus ground emergency medical services (GEMS), have shown underlying heterogeneity as these options have completely different routes and consequent times with reference to one patient. To compare the 2 types of transportation on a case-by-case basis, we analyzed the retrospectively reviewed HEMS and predicted GEMS data using an open-source navigation software.

Patients transferred by military HEMS from 2016 to 2019 were retrospectively enrolled. The HEMS records on the time of notification, injury point and destination address, and time required were reviewed. The GEMS data on distance and the predicted time required were acquired using open-source social navigation systems. Comparison analyses between the two types of transportation were conducted. Furthermore, linear logistic regression analyses were performed on the distance and time of the two options.

A total of 183 patients were enrolled. There was no statistical difference ($P = .3021$) in the distance between the 2 types of transportation, and the HEMS time was significantly shorter than that of GEMS (61.31 vs 116.92 minutes, $P < .001$). The simple linear curves for HEMS and GEMS were separately secured, and two graphs presented the statistical significance (P) as well as reasonable goodness-of-fit (R^2). In general, the HEMS graph demonstrates a more gradual slope and narrow distribution compared to that of GEMS.

Ideally, HEMS is identified as a better transportation modality because it has a shorter transportation time (56 minutes saved) and a low possibility of potential time delays (larger R^2). With a strict patient selection, HEMS can rescue injured or emergent patients who are “out of the golden hour.”

Abbreviations: GEMS = ground emergency medical system, HEMS = helicopter emergency medical system, MEOC = Medical Emergency Operation Center.

Keywords: ambulance, ground, helicopter, navigation, transportation

Editor: Wen-Jun Tu.

Statement of Ethics: The current study was approved by the Institutional Review Board of the Human Research Center of the Korean Armed Forces Medical Command (AFMC-20-IRB-024), and informed consent was waived due to the retrospective design.

Funding source: The authors did not receive any funding.

Conflict of interest statement: The authors have no personal, financial, or institutional interest in any of the drugs, materials, or devices described in this article. No financial support has been received in association with this submission.

All data generated or analyzed during this study are included in this published article [and its supplementary information files].

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How to cite this article: Jang JY, Kwon WK, Roh H, Moon JH, Hwang JS, Kim YJ, Kim JH. Time-saving effects using helicopter transportation: comparison to a ground transportation time predicted using a social navigation software. *Medicine* 2021;100:27(e26569).

Received: 15 February 2021 / Received in final form: 6 June 2021 / Accepted: 7 June 2021

<http://dx.doi.org/10.1097/MD.00000000000026569>

1. Introduction

It is widely accepted that the “Helicopter emergency medical service (HEMS)” has a shorter prehospital time compared to the “Ground EMS (GEMS),” and both services may be used to save an injured patient by facilitating their arrival at the hospital within the “golden hour.”^[1–4] Beyond the controversies on the cost-effectiveness and practical outcomes of HEMS,^[5–9] most clinicians would agree with the immediacy of HEMS especially when the patient is located in a rural area or in places that have poor ground traffic conditions.^[10]

Usually, when patients are injured, they have two transportation options: helicopter and ground ambulance. These have completely different routes and consequent time taken; therefore, they should be compared on a case-by-case basis.^[11,12] Practically, the patient chooses one of the transportation options and the result of the other option cannot be secured. Therefore, the majority of the literature compare the two options with underlying heterogeneity.^[13–16]

If we have the injured patient’s “exact address” and the “day and time” when the transportation began, we can predict the

distance and time of GEMS by using an open-source navigation software.^[17] Since the Medical Emergency Operating Center (MEOC) of the Korean Armed Forces Medical Command provides a helicopter transportation system for military medical welfare and regards it as one of the important military missions or operations, the data on patient location and time can be precisely recorded.^[18] By reviewing the records and comparing the data, we can directly calculate “the practical time saved,” which may influence the decision on the transportation modalities in clinical settings. Here, we attempted to secure the ideal linear curve of the distance and time of the two transportation systems, and calculate the exact time saved by using an open-source social navigation system.

2. Methods

2.1. Patients

We retrospectively reviewed the patients who were notified of the MEOC and transported by military HEMS from January 2016 to December 2019. The inclusion criteria were as follows: patients

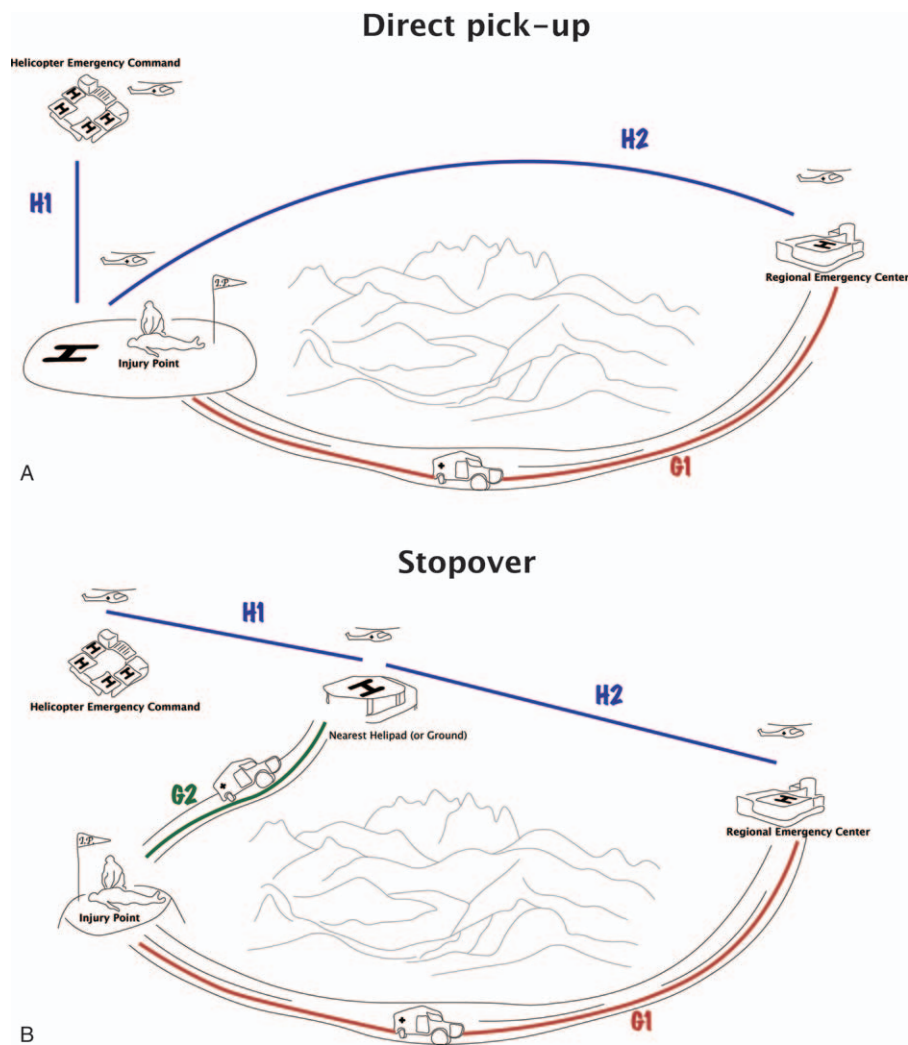


Figure 1. Two situations of helicopter transportation. If there is a helicopter landing at the injury point (A), the patient can be picked up directly. If there is no landing (B), the helicopter should stop over at the nearest helipad to pick up the patient.

who had the exact injury point address and time of notification, and were transferred by military medical helicopters (KUH-1, Korea Aerospace Industries, LTD., Gyeongsangnam-do, Korea). Patients were excluded if they used public helicopters, the exact injury point address was not assessable (military secrets), or ground transportation was not available for comparison such as those at high mountains or islands. Data on the patients' general demographics were obtained including age, sex, disease conditions, detailed transportation courses, and their destinations. The present study was approved by the Institutional Review Board of the Human Research Center of the Korean Armed Forces Medical Command (AFMC-20-IRB-024), and informed consent was waived due to the retrospective design.

2.2. Transportation settings

In the military medical system, when patients are injured, a rapid transportation system (from the injury point to the suitable hospital) is operated after direct notification to the MEOC. Usually, the nearest military doctor arrives at the injury point, and subsequently makes a decision regarding the transportation modality based on his experience and information from the navigation software. If the situation and time required by GEMS are acceptable, direct GEMS starts from the injury point to the nearest emergency center (G1). If they are not acceptable, HEMS could be started through 2 different models depending on the availability of injury points on the helicopter's landing: direct pick-up, and stopover. There are five distributed military helicopter emergency commands, and the nearest helicopter departs to the injury point or helipad that is closest to the patient. The transport settings and model are illustrated in Figure 1.

2.3. Data acquisition of HEMS and GEMS

We obtained data by reviewing the records of HEMS transportation including the day and time of notification, injury point address, the address of the nearest helipad (if used), each time required, and destinations. Figure 1 presents the categorical time and distance of HEMS.

The distance and predictive time required for GEMS transportation are acquired using open-source social navigation systems. Every distance was measured using an online map software (<http://map.naver.com>, NAVER Co., Gyeonggi-do, Korea), and the predicted time required is taken from another navigation software (<http://tmap.co.kr>, SK TELECOM Co., Seoul, Korea) as it provides day-by-day and time-by-time predictions. Figure 2 illustrates the distance and time comparisons between the 2 transportation systems.

2.4. Statistical analysis

Continuous values are presented as mean and standard deviation, and categorical variable data are presented as frequency and percentages. Nonparametric Wilcoxon signed rank tests were performed to compare the baseline parameters (distance and time) of the 2 types of transportation. To secure the ideal linear curve between the distance and time parameters in the two transportation systems, simple linear regression analyses were performed. Statistical significance was considered at $P < .05$. Statistical analyses were performed using a standard software (version 23.0, SPSS, IBM, Chicago, IL).

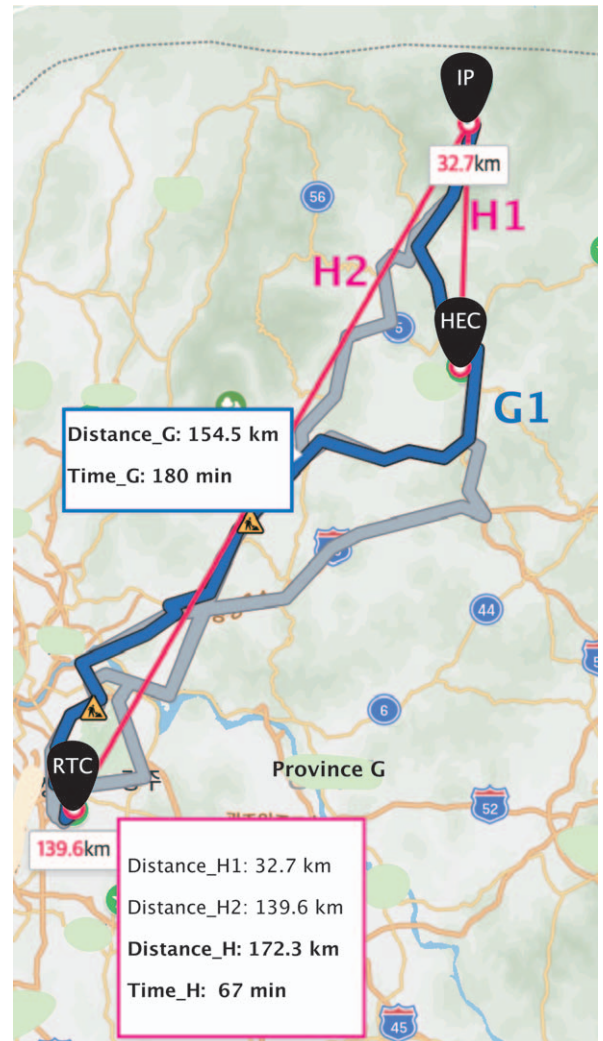


Figure 2. The captured image of social navigation software. The direct airline distances (H1: helicopter command to injury point, H2: injury point to destination) and practical road distance (G1) are measured. The time required by ground is predicted using a navigation software, whereas that of the helicopter is acquired by retrospective chart review. HEC, Helicopter emergency center; IP, Injury point; RTC, Regional trauma center

3. Results

In total, 326 patients notified MEOC of their emergencies. Of the 326 patients, 143 were excluded for utilizing a public helicopter ($n=74$), unavailability of ground transportation ($n=25$), and inaccessibility of the injury point address ($n=44$). Finally, 183 patients were enrolled, and the flowchart of patient enrollment is shown in Figure 3.

The general demographics of the sample are shown in Table 1. Owing to military secrets, several pieces of information are blinded. Of the 183 patients, 124 were transported after waiting for the arrival of the helicopter at the injury point (Situation A), whereas 59 patients were moved to the nearest helipad for safe helicopter landing (Situation B). As shown in Figure 4A, there was no statistical difference in the distance between the two transportation systems ($P=.3021$); however, the transportation time of HEMS was significantly shorter than that of GEMS (61.31 ± 22.03 vs 116.92 ± 33.34 , $P < .001$).

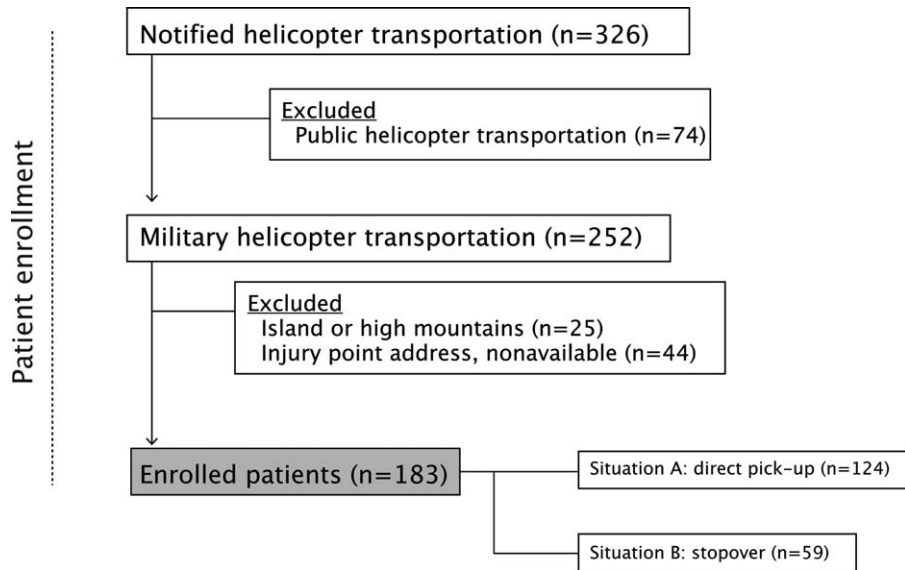


Figure 3. The flowchart of patient enrollment.

To integrate the 2 different situations, we compared the “H1 (helicopter from helicopter emergency command to the nearest helipad)” and “G2 (ground ambulance from injury point to the nearest helipad)” time in the “stopover situation (B) in Figure 1.” As shown in Figure 4B, among 59 patients who moved to the

nearest helipad to have access to HEMS, every H1 time is larger than that of G2 (except one case). In other words, the helicopter’s waiting only occurred in one case (marked with red spot; 5 minutes); therefore, the time of HEMS (H) was defined as the sum of H1 and H2, and that of GEMS (G) was defined as G1 (G2 ignored).

Table 1		
General demographics of the enrolled samples.		
Enrolled patients (n = 183)		
General		
Age	blind	
Sex	blind	
Disease conditions		
Extremity injury	40 (21.86%)	
Airway, breathing problem	25 (13.66%)	
Traumatic brain injury	18 (9.84%)	
Acute abdomen	18 (9.84%)	
Multiple trauma	17 (9.29%)	
Arrest, including hanging	12 (6.56%)	
Stroke (ischemic/hemorrhagic)	11 (6.01%)	
Pneumothorax	7 (3.83%)	
Myocardial infarction	5 (2.73%)	
Shock	5 (2.73%)	
Spinal cord injury	3 (1.64%)	
Others	22 (12.02%)	
Situation		
A: Direct pick-up	124 (67.76%)	
B: Stopover	59 (32.24%)	
Helicopter starting point (blinded)		
CC	83 (45.36%)	
PC	53 (28.96%)	
YG	26 (14.21%)	
YI	12 (6.56%)	
HL	9 (4.92%)	
Parameters	Helicopter	Ground
Distance, km	126.13 ± 70.69	120.75 ± 49.10
Time, min	61.31 ± 22.03	116.92 ± 33.34
Time saved, min	55.61 ± 27.71	

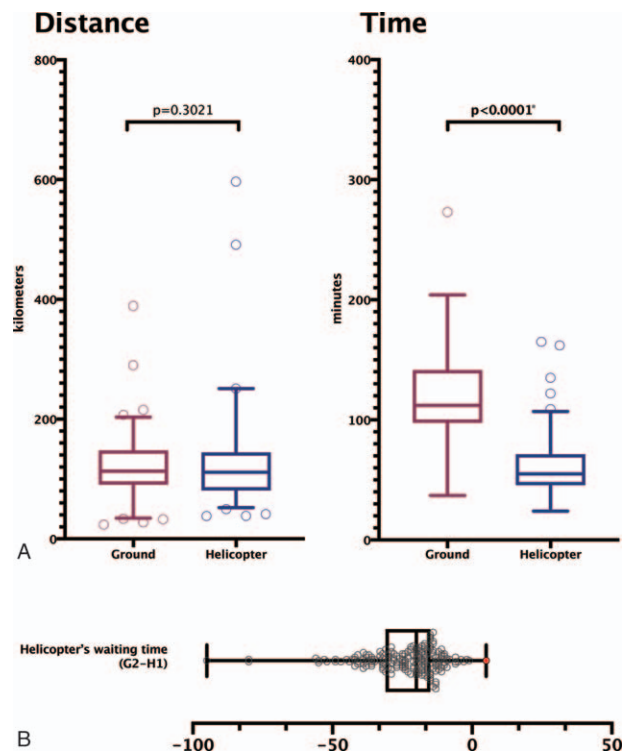


Figure 4. The plots of the distance and time of the two types of transportation with the results of the Wilcoxon signed rank tests (A) and helicopters’ waiting time (B).

Results	HEMS	GEMS	Time saved (H-distance)	Time saved (G-distance)
Slope	0.2739	0.5483	0.04327	0.2073
Std. error	0.01106	0.02979	0.02896	0.03902
95% CI	0.2520 to 0.2957	0.4895 to 0.6071	-0.01386 to 0.1004	0.1303 to 0.2843
Y	26.76	50.71	50.15	30.59
X	-97.73	-92.48	-1159	-147.6
Equation	$Y=0.2739^*X + 26.76$	$Y=0.5483^*X + 50.71$	$Y=0.04327^*X + 50.15$	$Y=0.2073^*X + 30.59$
R ²	0.7722	0.6518	0.01219	0.1348
P	<.0001	<.0001	.1368	<.0001

CI = confidence interval, GEMS = ground emergency medical system, HEMS = helicopter emergency medical system.

The results of the simple linear regression analyses are presented in Table 2, and their graphs are plotted in Figures 5 and 6. The ideal curves for HEMS and GEMS are separately secured with statistical significance as well as reasonable goodness-of-fit (Fig. 5). Compared to GEMS (B), HEMS (A) shows a better fit in terms of gradual slope and narrow distributions.

The times saved according to the distances were independently acquired (Fig. 6). Only significance is noted based on ground kilometers (B); however, both curves show poor goodness-of-fit (explanation abilities).

4. Discussion

In our results, the average time required by HEMS was 61 minutes, which was 56 minutes shorter compared to that required by GEMS. Furthermore, we successfully secured ideal linear curves for the two transportation systems (between distance and time required). By using the curves and exact injury point and destination addresses, we can finally calculate the time saved, which can be a good reference for making a decision on the transportation modality.

HEMS was originally used as air transport in military evacuation during the Korean War, and its use in civilian

situations was initiated in the 1960s in the United States.^[19,20] Since then, the HEMS has been successfully utilized in the transportation of injured victims to trauma centers in several advanced countries (especially those with broad territories), and the role of air transportation in long distances, hostile environments, and difficult geographical areas that cannot be accessed by ground ambulances has been undisputed.^[13] However, the setting for HEMS requires a great deal of human as well as other fundamental resources after social agreements. Furthermore, the effectiveness of HEMS remains controversial, such as in countries with small territories with good ground traffic conditions.^[5,10,15,19] Several studies have highlighted the importance of reducing the helicopter transportation of near-hospital injuries and over-triage of minor injury patients for air transportation to achieve better cost-effectiveness and practical mortality or disability reductions in HEMS.^[5,9,21]

In South Korea, 17 regional trauma centers have been evenly distributed across the country for the provision of superior medical services to patients with emergent and traumatic diseases. In these centers, several efforts have been made to utilize helicopter transport including a pilot project referred to as “Doctor Heli 2011”^[16]; however, HEMS failed to be set-up such that only 237 patients of a total of 139,072 major medical emergency patients were airlifted by helicopters (0.001%).^[11] This

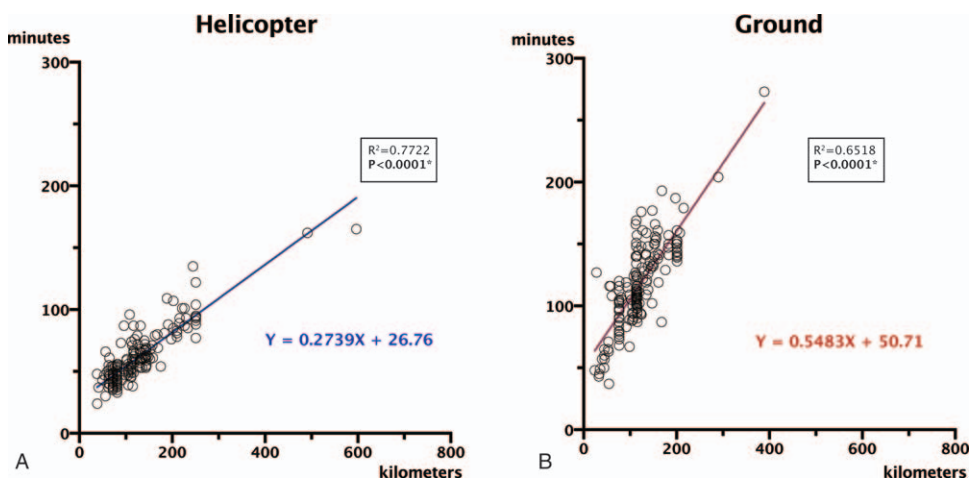


Figure 5. The graphical plots of the distance and time in HEMS (A) and GEMS (B). GEMS = ground emergency medical system, HEMS = helicopter emergency medical system

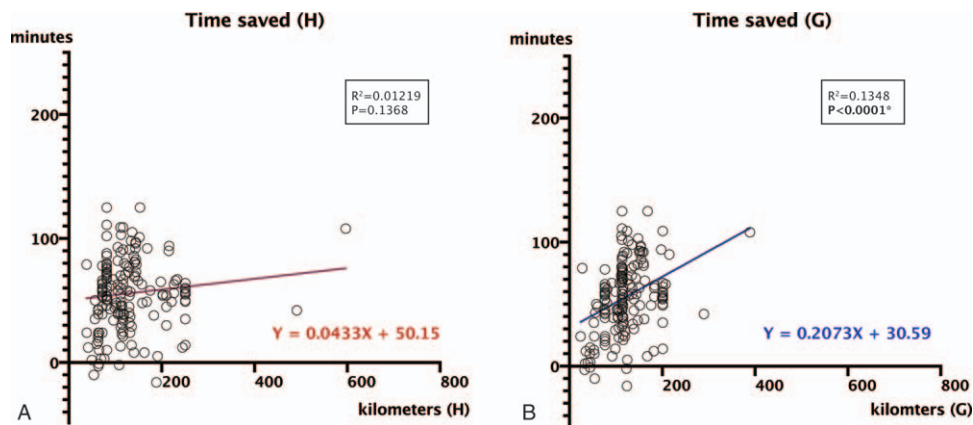


Figure 6. The graphical plots of the time saved based on the distance of HEMS (A) and GEMS (B).

might be related to the poor fundamental support from the government and insufficient social understanding that cost-effectiveness cannot be fully achieved due to the geographic characteristics of South Korea (small territory, high urban population density, and excellent road-traffic networks). Currently, HEMS is only operated in four institutions, and a nationwide expansion of the service is mandatory.

In contrast, in 2015, the MEOC set up a military HEMS and managed every case of emergency notification. From 2015 to 2019, a total of 573 patients were notified of their transportation from camps (or initial frontline medical facilities) to a suitable emergency center by HEMS. A relatively large volume of helicopter transportation is available in a single command (compared to the total number of regional trauma centers) as the military HEMS can be fully equipped, as covered by the Ministry of National Defense budget. Furthermore, since military corps are usually located on the frontlines that are far from urban areas, the distance from the injury point to the hospital makes it suitable to utilize HEMS. To date, the MEOC directly offers HEMS for military medical welfare as well as preparation for handling a potential mass casualty situation due to injuries that occur during wartime combat. In addition, as the MEOC does not pursue profits from the utilization of HEMS, a comparison between the 2 modalities can be objectively conducted. Here, we compared the 2 transportation modalities (helicopter vs ground ambulance) and identified several different characteristics.

First, both types of transportation can be started simultaneously (after notification); however, the starting points are different in that a ground ambulance is usually directly available from the injury point, whereas a helicopter should move from the command to the injury point to begin patient transportation. Therefore, each transportation has a completely different route. As shown in Figure 1, helicopters usually need additional transfer, indicated as “H1”; however, H2 can be shortened by using an air route. However, if ground transportation has to be used in this case, then the transportation directly starts by using G2, which is dependent on the road condition and traffic situation. However, the majority of previous studies have compared two modalities by considering different patient groups.^[13,15,22,23] This might induce a significant heterogeneity between the groups, and objective comparison cannot be secured. By using a navigation software, we obtained each patient’s

“practically used airline route” and “predicted ground traffic route,” and finally, the groups indicated a similar range of distance without any significance ($P = .3021$, Fig. 4A).

Second, the practical HEMS pre-hospital time was significantly shorter than the predicted GEMS pre-hospital time (Fig. 4A, $P < .0001$). It is clear that approximately 56 minutes can be saved by using HEMS when the injury points are located on an average of 120 km (or 116 minutes) far from the hospital. Beyond controversies, the “golden hour” is a well-known lexicon among trauma surgeons and EMS providers, and the underlying tenet of this adage suggests an injured patient has 60 minutes to receive definitive care from time of injury, after which chances of morbidity and mortality significantly increase.^[4,24,25] In our results, HEMS can enable the injured patients who are in over one-hour distances from hospital to arrive at the emergency centers within the “golden hour.”

Third, both types of transportation are significantly associated with a simple linear curve, but the slope of the graphs differ (0.2739 of HEMS vs 0.5483 in GEMS, Fig. 5). It can be interpreted that the average HEMS speed is twice as fast as that of GEMS. The greater the distance from the hospital, the more the time that can be saved. As mentioned, only a few studies that compare the slope or curves (between distance and time) of the modalities have been reported,^[22,26] and to the best of our knowledge, the current result is the first curve in Korean HEMS circumstances. Furthermore, the R^2 parameter, which refers to the goodness-of-fit of the ideal curve, is higher in HEMS (0.7722 in HEMS vs 0.6518 in GEMS).^[27] It may be inferred that the HEMS is accompanied by a lower possibility of transportation delays and is less dependent on unpredictable interfering factors. Beyond the controversies on cost-effectiveness, HEMS can be regarded as an ideal “predictable” transfer modality for patients who are in over an-hour distances.

In fact, we failed to secure the ultimate curve for the time saved as it was not significant and displayed poor R^2 parameters (Fig. 6). As the 2 modalities have totally different routes and consequent curves, they cannot be easily integrated into one simple curve. Instead, by using 2 curves, we can assess the time saved, which is the final value for a physician to use when deciding on the transportation modality. The HEMS graph (Fig. 5A) has both significance and goodness-of-fit; it can be used as the basic curve for Korean HEMS circumference of Gyeonggi-

Gangwon province. By combining it with the social navigation software, each transportation time can be minutely analyzed. A future development of a software or application may provide wide accessibility for EMS-involved persons such as physicians, emergency medical technicians, and EMS providers.

The present study has several limitations. First, cost-effectiveness was not analyzed. Because of the distinct characteristics of military medicine, the HEMS can be utilized without considering the operating profits. A comparison of budgets between HEMS and GEMS can be a good reference for policymakers. Second, patient factors, including the severity of injury and outcomes, were not included. The analyses were based on the documentation from MEOC, which precisely recorded the information on “helicopter transportation,” including the injury point address and destination, and each time required. The detailed patient information could only be assessed after reviewing each destination hospitals’ medical records, which were not included in this study. Third, the results or graphs of the present study cannot be generalized since the road traffic condition and hospital distribution may differ among the provinces and/or countries. However, the platform of the study can be easily adapted to other situations using retrospective data and navigation software.

5. Conclusion

We analyzed the time required for two modes of transportation by using retrospectively reviewed HEMS data and navigation-based GEMS predicted data. Two simple HEMS and GEMS linear curves were successfully acquired with significance and goodness-of-fit. Ideally, HEMS was identified as a better transportation modality because of the shorter transportation time and a low possibility of potential time delays. With a strict patient selection, HEMS can be used to salvage injured or emergent patients who are “out of the golden hour.”

Author contributions

Conceptualization: Ji Young Jang, Woo-Keun Kwon, Jong Ha Moon, Yoon Jic Kim, Jang Hun Kim.

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Software: Jang Hun Kim.

Supervision: Jang Hun Kim.

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Visualization: Jang Hun Kim.

Writing – original draft: Jang Hun Kim.

Writing – review & editing: Woo-Keun Kwon, Jang Hun Kim.

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