

Access this article online
Quick Response Code:

Website: www.jehp.net
DOI: 10.4103/jehp.jehp_36_21

Factors affecting development of air ambulance base: A systematic review and thematic analysis

Zahra Eskandari¹, Zohreh Ghomian^{1,2}, Sanaz Sohrabizadeh³, Ahmad Alibabaei⁴, Hojjat Ahmadinejad⁵

¹Department of Health in Disasters and Emergencies, School of Public Health and Safety, Shahid Beheshti University of Medical Sciences, Tehran, Iran, ²Workplace Health Promotion Research Center, Shahid Beheshti University of Medical Sciences, Tehran, Iran, ³Safety Promotion and Injury Prevention Research Center, School of Public Health and Safety, Shahid Beheshti University of Medical Sciences, Tehran, Iran, ⁴Department of E-Learning, Virtual School of Medical Education and Management, Shahid Beheshti University of Medical Sciences, Tehran, Iran, ⁵National Center for Strategic Research in Medical Education, Ministry of Health and Medical Education, Tehran, Iran

Address for correspondence:

Dr. Zohreh Ghomian, Department of Health in Disasters and Emergencies, School of Public Health and Safety, Shahid Beheshti University of Medical Sciences, Tehran, Iran.
E-mail: zghomian@sbm.ac.ir

Received: 09-01-2021
Accepted: 16-03-2021
Published: 31-08-2021

Abstract:

Nowadays, air ambulances have been developed as part of advanced emergency medicine services with many countries employing these services for transferring patients in usual and emergency conditions. However, there are challenges concerning the optimal development of air ambulance base. The present research aimed to identify factors affecting the development of air ambulance bases to provide the opportunity of planning to improve the quality of emergency medical services. In this systematic literature review, the peer-reviewed papers in five electronic databases, including Medline through PubMed, Scopus, Web of Science, ScienceDirect, and ProQuest, as well as available gray literature, were searched and selected. Two combinations of groups were used as keywords: the Health Planning and development factor, air ambulance base. The focus was on the PRISMA checklist, with no time limitations until from 1990 to January 2020. Finally, through 5156 related citations, 20 articles were included. Descriptive and thematic content analyses were evaluated. The factors affecting the development of the air ambulance base were classified in five categories and 14 subcategories as follows: navigation criteria, process indications and standards, sociopolitical factors, and current situation of the area. There are few studies on factors affecting the development of air ambulance bases. It is necessary to apply multidimensional models to consider various factors for development. The development of high populated cities, events and ceremonies with a crowd of participants, and increase of human-made disasters are making these services increasingly indispensable.

Keywords:

Air ambulance, air ambulance base locations, base, development, emergency helicopters, helicopter emergency medical service, systematic review

Introduction

It has been reported that about 86% of deaths due to trauma and 64% due to cardiac arrest occur before arriving to the hospital.^[1] This may be for a variety of reasons, including the distance between the scene of the accident and location of emergency services, lack of access to the scene, or the need for secondary transfer from the primary care center to a specialized hospital as well as advanced trauma centers. In such circumstances, air ambulance can

play a crucial role in accessing patients and transferring them from the accident scene, as well as survival of the patients and the injured.^[2-4] As part of the emergency medical system, an air ambulance is one of the fastest and most efficient approaches of transporting the injured and sick in emergencies, natural disasters, and road traffic injuries. It can overcome geographical obstacles such as mountains, trees, and long distances, and save the life of patients in inaccessible areas.^[5-7] Thus, the appropriate location of air ambulance bases is very important because inappropriate decisions

This is an open access journal, and articles are distributed under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike 4.0 License, which allows others to remix, tweak, and build upon the work non-commercially, as long as appropriate credit is given and the new creations are licensed under the identical terms.

For reprints contact: WKHLRPMedknow_reprints@wolterskluwer.com

How to cite this article: Eskandari Z, Ghomian Z, Sohrabizadeh S, Alibabaei A, Ahmadinejad H. Factors affecting development of air ambulance base: A systematic review and thematic analysis. *J Edu Health Promot* 2021;10:320.

about the location of the facility have serious impacts on outcomes.^[8] Air ambulance provides fast and quality response by minimizing response and transfer time as well as with the maximum population coverage and demand response.^[9] One of the important factors of health management in accidents and emergencies is the good location or development of emergency facilities to cover the maximum areas and provide optimal services to patients.^[10] Emergencies are unpredictable in terms of time and place.^[11] Establishing facilities in a suitable place reduces the response time and services to the injured and medical centers, which is one of the important goals of the emergency medical service system.^[12] The right place for emergency medical services is a solution to providing medical services by achieving the goal of maximum coverage and reducing the time as well as distance of the route, plus infrastructure costs.^[11] Studies have shown that optimal development of air ambulance bases reduces response time, increases the number of populations covered, and reduces the mortality rate.^[13,14]

Nowadays, air ambulances have been developed as part of advanced emergency services such that many countries use these services for transferring patients in usual and emergencies.^[15] However, there are challenges concerning the optimal development of air ambulance bases. Thus, the present research aimed to determine the effective factors on the development of air ambulance bases to provide the opportunity of planning required for improving the quality of emergency medical services.

Materials and Methods

This study was a systematic literature review conducted based on the PRISMA protocol. It was registered in an international database called Prospero, with the registration number 42020166036.

Inclusion and exclusion criteria

All English papers and articles related to the factors affecting the development of the air ambulance base were included in this study. They consisted of original quantitative research (case report, case series, and cross-sectional) and qualitative research (content analysis, phenomenology analysis, and grounded theory) and review studies (narrative, comprehensive, and systematic), which were published from 1990 to January 2020. Non-English papers, books, theses, letters to editors, and papers without abstract were excluded. Furthermore, papers unrelated to the factors affecting the development of air ambulance or air relief systems were removed.

Databases and search strategy

The search syntax was conducted using the air

ambulance base development as the main keywords. Furthermore, appropriate synonyms for keywords were identified through Medical Subject Headings, to increase the probability of identification of all relevant literature, with these keywords selected based on an agreement of three researchers (ZGH, ZE, and SS).

The search for articles was carried out in the electronic databases including Medline, PubMed, Scopus, Web of Science, ProQuest, and ScienceDirect. Furthermore, Google Scholar was used to search for gray articles. AND/OR Boolean operators were used to write syntax. The syntax writing method for each of the above databases was completed separately. The search words were employed in the titles, abstracts, and keywords of the used articles. According to the guide, the search was performed in all databases. All studies focusing on factors affecting the development of the air ambulance base were included. The initial search syntax for PubMed was as follows:

((“Health Planning”) OR (Development)) AND ((Base) OR (Bases)) AND (“Air Ambulance”) OR (Ambulance AND Air) OR (“Emergency Helicopters”) OR (“Emergency Helicopter”) OR (Helicopter AND Emergency) OR (Helicopters AND Emergency) OR (“Helicopter Ambulances”) OR (Ambulance AND Helicopter) OR (Ambulances AND Helicopter) OR (“Helicopter Ambulance) OR (Helicopter) OR (Aircraft) OR (HEMS) OR (Hems) OR (“Locating helicopter”) OR (“Helicopter Transport”) OR (“Helicopter Utilization”) OR (“Air Ambulance base”) OR (“Air medical”) OR (“Air Emergency medical”) OR (“Helicopter Ambulance Stations”) OR (“Multi-period facility location problem”) OR (“Aero medical”) OR (“Location-coverage models”) OR (“air Ambulance base locations”) OR (“Helicopter Emergency Medical Service”) OR (“Air medevac”) OR (“location-allocation problem for air ambulance and Helicopter) (“Air Ambulance location problem”) AND (1990/01/01:2020/01/02)).

Data collection process and quality assessment

In this study, all reviewed studies were transferred to EndNote software version 7 and duplicate references were removed. The initial screening of the studies was performed by two independent researchers (ZGH and ZE) based on the information contained in the titles and abstracts.

Then, the two authors independently screened the original articles by reviewing the titles and abstracts of the articles with the selected articles divided into three groups: relevant, irrelevant, and unsure. Articles that were not relevant were excluded from the study. Each researcher reviewed the full text of the remaining articles based on inclusion and exclusion criteria. The research

team discussed any disagreement in the selection of final papers in cases where no agreement was reached; the opinion of the third person on the research team was the final decision to include the article. After the agreement, the final studies were evaluated based on quality assessment tools.

The quality of all selected papers was assessed using critical appraisal tools including Critical Appraisal Skills Programme (CASP), Newcastle–Ottawa Scale (NOS), and The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE). NOS consisted of eight ranking 0 or 1 (8); CASP checklist has three sections and totally 10 questions with answers yes, no, and unsure. STROBE checklist included 22 questions which embrace all aspects of the study. Each study was scored between 0 and 44. The authors applied STROBE tool for assessing papers with mathematical model. The data extracted from each study were presented in two sections as descriptive section and subject/quality content. The first section was related to general characteristics of the paper (main author, publication year, country/methods/study domain/study year), and the second section included effective factors on the development of the air ambulance bases [Table 1].

For extracting the results of the qualitative articles, with regard to the aim of the study, we analyzed the findings of the articles profoundly. For these articles, thematic analysis method was applied, which consisted of six steps: (1) familiarity with data, (2) generating primary codes, (3) searching for themes, (4) reviewing the theme, (5) defining the themes, and (6) producing the report.

Results

According to the processes of PRISMA diagram, 5664 related papers were found. After removing the duplicate cases as well as cases meeting exclusion criteria, 20 studies were selected for final analysis [Figure 1].

Among 20 studies, 9 were qualitative, 3 quantitative, 5 mathematic modeling, and 3 mixed methods papers. More than 75% of the studies were conducted during 2010–2019. Regarding the results of the present study, among the effective factors, response time, the distance between the base and accident location and health centers, the covered population, and the events were 40%, 36%, 30%, and 26%, respectively, more influential than others in optimal development of air ambulance bases [Table 1].

To analyze the extracted data, thematic analysis method was used which had five steps. First, familiarization with the data obtained from the results and conclusions of other studies was done, after which 34 initial codes were extracted

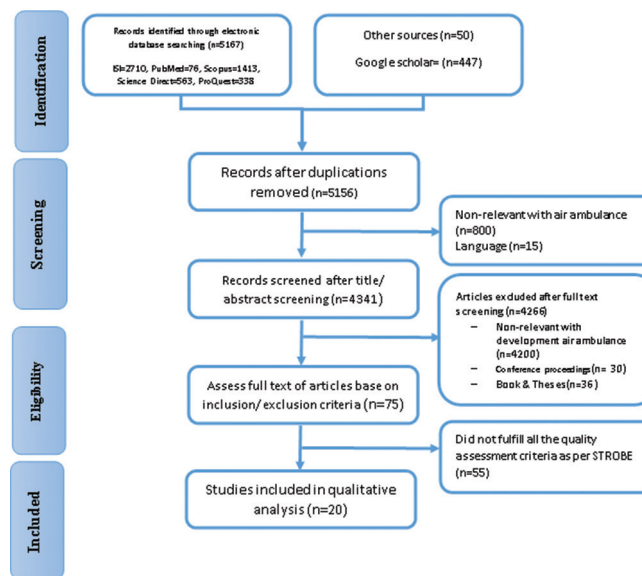


Figure 1: PRISMA flow diagram of selected studies in a systematic review of factors affecting the development of the air ambulance base

based on the results of the studies. Next, based on the extracted initial codes, themes were searched and five main themes were extracted. After extracting the main themes, the themes were reviewed according to the subthemes.

As shown in Table 2, based on the findings of this study, the effective factors in the development of air ambulance bases in 5 main categories and 14 subcategories, included navigation criteria (flight equipment, criteria); geophysics criteria, resources (personnel, cost, and safe compensation), process indicators and standards (dispatch indications, time process indicators, distance/distance criteria, and access criteria), political and social factors (political factors and social status), and urban context (current situation of the region (hospital network information, accident status, and service coverage) were extracted.

Navigation criteria

According to the findings, among the effective navigation criteria, the most important ones concerning the development of air ambulance bases were flight technical equipment (presence of Medicopter, flight support system, communication equipment, and night-vision equipment) and geographical criteria (land gradient, proper position of pad, weather condition, and flight radius).

Flight technical equipment

The presence of Medicopter, flight support system, communication equipment, and night-vision equipment were the effective factors of flight technical equipment for base development.

The equipment used in air ambulance are divided into

Table 1: The studies were mostly conducted factors affecting the development of the air ambulance base

Authors/year	Study type	Country/ location study	Outcome	Conclusion/suggestion
Pappinen <i>et al.</i> , 2019 ^[16]	Quantitative	Finland/National	Approximately 90% accepted missions took place within 100 km from the base and 10.9% occurred outside of the administrative service area Calculating the 95% convex hull areas for all Finnish HEMS units results in service areas that overlap at some points	Incorporates mission locations could offer a standardized and comparable solution for determining actual HEMS unit service areas
van den Berg <i>et al.</i> , 2019 ^[17]	Mathematical model	Norway/ Provincial	By relocation and change minor changes to base locations, service coverage can be increased from 93.46% to 97.51%	As the load of the system increases, focus of the model shifts from providing single coverage in low-demand areas to backup coverage in high-demand areas
Matthew Miller Ilana Delroy-Buelles, 2019 ^[18]	Quantitative	United Kingdom/ National	Little evidence of geographic difference in scene outcome for trauma patients attended by HEMS services	Geographic location and distance from base to scene did not appear to be associated with an increased risk of mortality
Sorani <i>et al.</i> , 2018 ^[19]	Qualitative	Iran/National	Challenges experienced in providing and developing helicopter including infrastructure deficiencies, safety concerns for staff, patients and public, insufficient resource management, the problems related to staff competencies	Revision of helicopter development plans Developing national standards and regulations is prerequisite Determination of triage criteria
Firouzi Jahantigh and Ghaderi, 2018 ^[20]	Descriptive-analytical	Iran/Provincial	Criteria for selecting the best places for deploying air ambulances Proximity to the roads (w=0.244) Appropriate tilt area (w=0.083) Proximity to crowded areas (w=0.435) Proximity to high-risk passages (w=0.182) The convenient distance from the medical emergencies (w=0.057)	Location with different criteria and more such as distance, demand in each city, considering environmental conditions such as proper distance from fault and natural disasters
Navazi <i>et al.</i> , 2018 ^[21]	Mathematical model	Iran/Provincial	We can an augmented ϵ -constraint method is used to cope with the bi-objective problem that minimizes the cost and the arrival time	Future research directions, heuristic or meta-heuristic algorithms can be developed for solving large-sized instances
Røislien <i>et al.</i> , 2018 ^[22]	Quantitative + mathematical model	Norway/National	The existing bases covered 96.90% of the population and 91.86% of the incidents for time threshold 45 min	Use of population data as a proxy for incident data is thus not recommended The difference in the optimal number of bases and base locations between population and incident data seems to increase with lower target times
Røislien <i>et al.</i> , 2017 ^[14]	Quantitative + mathematical model	Norway/National	For a 45-min threshold, 90% of the population could be covered using four bases, and 100% using nine bases. Decreasing the threshold to 30 min approximately doubles the number of bases needed	Decreasing the target time might result in a nonproportional increase in the number of bases needed to fulfill such a goal
A hybrid modelling technique that optimizes response time for a given number of bases and minimum defined threshold of population coverage	Mathematical model	Australia/ National	Seven bases could cover 98% of the population within 45 min when optimized for coverage or reach the entire population of the state within an average of 21 min if optimized for response time	Garner and van den Berg, 2017 ^[13]

Contd...

Table 1: Contd...

Authors/year	Study type	Country/ location study	Outcome	Conclusion/suggestion
Shahriari <i>et al.</i> , 2017 ^[23]	Mathematical model	Iran/Provincial	Providing three models for the transport of the injured with the aim of reducing the total time of transfer from demand to hospital	Consider capacity for each emergency facility, the distribution of the ambulances in the demand areas and its impact on the time of ground EMS services due to geographic issues Implement the HEMS system by assuming disruption in the network
Bozorgi- Amir <i>et al.</i> , 2017 ^[24]	Mathematical model	Iran/Provincial	Providing three models for the transport of the injured with the aim of reducing the total time of transfer from demand to hospital	Consider capacity for each emergency facility, the distribution of the ambulances in the demand areas and its impact on the time of ground EMS services due to geographic issues
Hassani <i>et al.</i> , 2012 ^[25]	Descriptive	Iran/Provincial	The mean flight time, the time from the initial call until the patient was delivered to a medical facility, was 36.56 18.44 min	Tehran HEMS is still far from attaining optimal values, particularly regarding flight time
Nishikawa and Yamano, 2010 ^[26]	Quantitative	Japan/National	Factors that delay development are included: financial, lack of public and political awareness slows growth, legislation, and fundamental policy	The optimal number of Doctor-Heli programs, with consider the mountainous terrain and remote islands
Mortality rates have declined with the onset of HEMS in East Germany	Quantitative	German/National	The main organizational barriers to an effective HEMS disposition were based on technical issues and communication failures	Struk M F, 2010 ^[27]
Erdemir <i>et al.</i> , 2010 ^[28]	Quantitative + mathematical model	New Mexico/ state	Crash node and path coverage percentage values decrease when ground ambulances are utilized only within their own jurisdiction	We focus on all types of emergency situations, then we should consider area coverage instead of path coverage
Schuurman <i>et al.</i> , 2009 ^[29]	Quantitative	Canada/National	GIS-based protocol for location of emergency medical resources can provide supportive evidence for allocation decision - especially when resources are limited	Utilization statistic as well as qualitative investigation of the purported improve efficiency of the system given the use of evidence-based decision-making to locate the service
Erdemir <i>et al.</i> , 2008 ^[30]	Quantitative	New Mexico/ state	We found that the current system provides 97.5% weighted coverage to the state of NM considering a 10-min base to scene fly time, where the optimal design we can achieve 98.6% weighted coverage By locating additional aeromedical bases, we always attain the required coverage level with a lower cost than with locating additional trauma centers	For emergency services location application, considering crash path is critical Required level of coverage or for a given budget level, locating aeromedical base is more efficient due to the much lower costs of base as compared to TC
Flanigan <i>et al.</i> , 2005 ^[31]	Quantitative	U.S./National	More meaningful relationships may be developed by examining air medical coverage of actual crash locations rather than resident population locations	Future efforts using ADAMS will focus on examining actual geo-coded fatal crash locations relative to air medical coverage Many control factors for the effectiveness of air medical services can be taken into account as part of a multivariate statistical analysis

Contd...

Table 1: Contd...

Authors/year	Study type	Country/ location study	Outcome	Conclusion/suggestion
Heggestad and Børsheim, 2002 ^[32]	Quantitative	Norwegian/ National	The helicopter service (HEMS) has short access times, with a mean reaction time of 8 min and a mean response time of 26 min for acute missions. Nearly all patients (98%) are reached within 1 h. Multivariate analyses showed that the distances of the patients from the nearest helicopter base and the nearest hospital are significant determinants for the use of HEMS	Safety, cost-containment, and gatekeeper functions remain challenges
Clark <i>et al.</i> , 1994 ^[33]	Quantitative (simulated)	United States/ state	For each simulated event, if the injuries were sufficiently severe, if weather permitted flying, if the occurrence was not within 20 miles of a center or outside the range of the helicopter, and if the helicopter was not already in service, then it was used for transportation	Discrete-event simulation is a potentially useful tool in planning for EMS systems Numerous political and other considerations which would be more difficult to model, such as the possibility of patients transported across state lines, and the costs of maintaining the helicopter and its crew in different locations

EMS=Emergency medical services, HEMS=Helicopter EMS, TC=Trauma center

Table 2: Factors affecting the development of the air ambulance bases, a systematic review

Classification of the factors affecting the development of air ambulance base				
Main category	Category	Subcategory		Citation
Effective factors on development of air relief bases	Navigation criteria	Flight technical equipment	-	[34]
		Geophysical criteria	-	[20,22,31,33]
	Sources	Personnel	-	[19]
		Financial sources	-	[26]
		Equipment safety	-	[19]
	Process standards and indications	Deployment indication	-	[19]
		Time process indication	-	[13,14,24,31-32]
		Distance/distance criteria	-	[16,20,24,32]
		Access criteria	-	[20,29,32]
	Social and political factors	Political factors	-	[19,26-27]
		Social situation and urban texture	-	[13,14,22-23,29]
	Currentsituation of area	Hospital network information/characteristics	-	[23,25,32]
		Event situation/events rate	-	[21,27,30,31,33]
Service coverage		-	[22,26,28,30,31]	

medical and nonmedical categories. Medical equipment consists of instruments and tools required for diagnosis, treatment, and reduction of injuries, while nonmedical equipment consists of communication equipment, safety, and extraction equipment.^[15] In order to provide timely and safe services by air ambulance, it is necessary to have technical equipment, besides medical equipment.^[34] Lack of a night-vision system causes the time of helicopter usage to be limited to the hours between sunrise and sunset,^[15] meanwhile access to this equipment would reduce accidents of air ambulances.^[35] Struck *et al.* pointed to the technical problems and communication defects as challenges of air ambulance application.^[27]

Geophysical criteria

Land gradient, proper position of pad, weather condition, and flight radius are the most important geophysical

factors in the development of air ambulance bases.

Land gradient as one of the geophysical criteria is vital in selection of landing zone of air ambulance as well as distance from the air ambulance. The landing zone must be flat, without gradient, visible from altitude, whereby people get near to or away it through downward gradient.^[36] Firouzi Jahantigh and Ghaderi considered the gradient as one of the influential factors in locating and developing air ambulance bases.^[20] The proper place for the base is of great importance, concerning the service coverage, because appropriate access to the event point, timely response, and the possibility of the injured transfer heavily depend on the base zone. However, according to studies, the geographical location and distance of the base of the accident site do not seem to be

associated with an increase in mortality.^[18] Climate and weather in each area, including temperature, humidity, altitude, and wind speed, are considered in selection of helicopter types and the development of air ambulance; 10% of missions of air ambulances around the world are canceled, because of bad weather conditions. This rate is even higher in Iran.^[15,37]

Flight radius of the air ambulance is one of the effective factors for maximum population coverage and responsiveness in development of air ambulance bases. It is also one of the crucial indicators for assessing the territorial coverage rate in the country.^[15] Pappinen *et al.* noted the flight radius of air ambulance for providing service as an influential factor in the development and usage of air transfer services. In this study, 90% of the missions occurred in distance of 100 km from air ambulance bases and only 10.9% of the missions had been occurring in longer distances.^[16] In Iran also, distance of 150 km is an important factor in locating the bases for coverage of byroads, paths, mountains, and villages.^[38]

Resources

Human resource, financial recourse, and equipment safety are among the most important effective factors in optimal development of air ambulance bases.

Human resources

According to the reports of some studies, there is a training syllabus for air ambulance personnel in some countries, including Norway, the United States, and England, consistent with their national standards,^[39] as their knowledge and skill are vital for providing high quality and safe services.^[40-42] Lack of training and personnel's incorrect perception of conditions of physical changes affect the patient physiology during flight, while also leading to the severity of injuries and side effects such as bleeding, hemothorax, and pneumothorax.^[43] A variety of personnel combination is used in air ambulance for providing services.^[26,44] Most of the differences are rooted in necessity of the presence of a physician in the helicopter. In general, there is disagreement on the ideal combination of the medical group,^[15] though studies revealed that the presence of a physician improves the quality of the services.^[39,45] Sahebi *et al.* suggested that comprehensive training programs should be implemented for effective management of the air emergency process during disasters.^[46]

Financial recourses

Providing budget and finance is an important and effective factor in sustenance of air ambulance services.^[21-23] High-cost air ambulance service is a crucial challenge in development and use of their services; however, disadvantages of these services for society and the benefits of these services in

saving the lives prove the service efficiency and value morally. It has been also demonstrated that air emergency medical services are cost-effective, concerning five diseases including trauma diseases, pregnant women, newborns, cardiac arrest, and brain stroke.^[15] Studies have shown that applying proper triage criteria for patient transfer may restrict usage of this expensive service.^[47,48] Purchasing services from organizations or companies providing air services is one of the factors influencing the use and development of air emergency medicine bases. Although saving lives is a definite virtue and the cost-effectiveness of these services is undeniable, one of the challenges of purchasing a service is the impossibility of changing the helicopter to a Medicopter unless the Medicopter is used as a service purchase.^[15]

Equipment safety

In the last two decades, there has been a constant concern over air ambulance safety, due to the nature of emergency missions.^[49] According to the American Transportation Safety Association, air ambulance personnel have the highest score in the ranking of dangerous occupations.^[50] Personnel responsibility and event insurance are necessary and the base commander must consider this necessity since there is a possibility of air ambulance crashes.^[15] Upgrading and equipping the fleet is considered as one of the most important factors to increase safety. According to the experience of other centers, the use of glasses equipped with avionics and night vision can significantly reduce air ambulance accidents.^[51] Setting up and implementing standard safety training is considered as one of the ways to reduce the risks of air ambulance.^[39] In addition, US Transportation Safety Association reports indicate the need for safety training and preparation for difficult and dangerous situations for medical staff.^[52]

Indications and standards of the process

Indications of deployment and time process, distance, and access criteria are the most important process indications and standards in the development of ambulance bases, and their determination is inevitable for achieving the goals of the base development. On the other hand, presenting the results of the indications and analysis to the higher officials leads to their active involvement and amending the processes of air emergency as well as the promotion of the indications.

Dispatch indications

For the optimal application of air ambulance, it is necessary to get familiar with deployment indications, as it leads to optimal air ambulance usage, providing timely and safe services, reduction of transfer time, and mortality.^[15] Distinguishing the injured who will benefit from air ambulance is a great challenge; therefore, determining the indications and criteria of patient

transportation by air ambulance is very important.^[5,53]

Deciding about the usage of air ambulance for transferring the patients and injured depends on many factors, including the required care level, the necessity to save time, special monitoring, drugs, equipment, or experts during transportation.^[54] Sorani *et al.* recommended to formulate triage criteria for the use of air ambulances with regard to the discussion of safety and cost of using air ambulances.^[19]

Process time indicators

Time is also one of the important factors of environmental factors; according to studies, 36% of articles considered it as an important and influential factor in planning for the development of air relief bases.^[17,21,23,25,31-33]

The purpose and philosophy of using air ambulance is to reduce the response time index because the probability of survival of the injured depends a lot of the response time.^[55] The probability of survival is highly dependent on the response time.^[56] Many experts believe that the first 60 min after the accident is a golden time for saving the injured due to the essential role of time in the survival of severely injured trauma patients, reducing the transfer time of critically ill and injured patients, and the ability to provide more medical services as well as rapid transfer to medical centers with appropriate services as essential requirements.^[57-59] Air transfer can play an important role in this issue and the survival of the injured^[60] since the chances of survival and rescue of trauma patients increase with timely transfer to medical centers.^[61] In another study (2011), it was proved that air ambulance application for transferring patients of 18–54 years could reduce mortality.^[60] Sánchez-Mangas *et al.* suggested that a 10-min reduction in the response time (from 25 to 15 min) in highways and roads could reduce the death probability to one-third.^[62] Providing services in the shortest possible time and saving time is the advantage of using an air ambulance. In addition to trauma patients, the prevalence of cardiovascular disease and stroke, as well as heart attack, has proven that in all of them, a golden time is crucial in transporting patients to the nearest medical center.^[38]

Distance/distance criteria

According to studies, 36% of articles have considered the appropriate distance to the medical emergency centers as an effective factor in the development of air ambulance bases.^[16,23,29,32-33] Access to the patient within proper time faces many restrictions, such as passing long distances and many physical obstacles.^[63] Air ambulance overcomes these problems and covers a wider area, relative to the ground ambulances. They can fly over mountains, trees, and long distances to save patients and injured people.^[7] Heggstad and Børsheim claimed

that distance between the patient and the nearest air ambulance base or hospital is an important factor for using an air ambulance.^[32]

Access criteria

Studies have considered access criteria as an important factor in the development of the air ambulance base. They include the appropriate location of the base, proximity to crowded centers, as well as access to transportation systems and high-risk passages.^[20,29] A study by Clark *et al.* showed that if the injuries were severe, the weather conditions allowed the flight to take place, the accident occurred within 20 miles (32 km) of the air ambulance base, and the helicopter was not on a mission, air transport could be used for transportation injured used.^[33]

Social and political factors

Social and political situations as well as urban context are among important factors in the development of air ambulance bases. One of the main concerns of policymakers is to establish justice in health system and easy access to health services. Commitment to health is an excellent goal in the health system.^[15]

Political factors

Policy and law-making are important in the development of air ambulance bases.^[26,27] In Japan, the government approved a rule for applying a helicopter to facilitate medical emergency services (2007). It was called the “Doctor-Heli Rule.” The purpose of this law was to find ways to reduce local government costs for helicopter operations by using health insurance and compensation insurance for workers’ accidents.^[26] In Iran, the government is obliged to provide necessary legal mechanisms to reduce 10% of road accident deaths annually, according to a timetable.^[15] Since air transfer plays a crucial role in reducing trauma patient’s death rate, such rules can affect the development programs of air ambulance bases.

Social situation and urban context

Another influential factor in the development of air ambulance bases is the social situation and the urban context, which has been studied as a development factor in articles.^[13,14,17,22,29,31] In Iran, more attention has been paid to the cost-benefit analysis of developing bases, with regard to the population and climate situation of the country (young population and cumbrous areas with scattered population).^[38] The emergency medical service system seeks to achieve rapid response with the maximum population covered.^[9] In a study by Garner *et al.*, they found that adding two air ambulance bases to the previous number could increase population coverage from 91% to 97% and reduce response time from 21 min to 19 min.^[13]

Current situation in the area

Hospital network information, event situation/event rate, and service coverage are among effective factors concerning the area situation.

Hospital Information Network

Registered hospital data are used in descriptive studies and for extracting the number of patients transferred to hospitals.^[25] They can also be used in the data analysis for optimal usage of an air ambulance to respond to events and to provide timely as well as safe response to medical emergencies by land and air ambulances.^[23] Applying the information about the location of the mission is a standard solution for developing and determining the areas in need of air ambulance services.^[16]

Event situation/event rate

Accident-prone points and accident hotspots are another factor influencing the development of air ambulance bases, which has been considered in studies as an important factor in the development.^[21,22,28,30,31] Reducing injuries after accidents is one of the main strategies that are the responsibility of health-care providers. Planning in the provision of prehospital services has led to a significant reduction in the mortality rate of trauma patients due to traffic accidents.^[64] Road accidents are the leading cause of death for children and adolescents aged 5–29 years as well as the eighth leading cause of death for all age groups.^[65] An air ambulance, as a provider of prehospital services, can transport critically ill patients and injured persons to hospitals^[66] while also helping manage major accidents by transferring equipment, personnel, and patients.^[67] When accidents with mass casualties occur in areas far from quick access to the hospital and medical facilities in the area are limited,^[68] air ambulances can be used to provide quick access to specialized and subspecialized services.^[69]

Service coverage

The amount of coverage of the geographic area of the country and traffic accidents are important indicators of air emergency monitoring.^[15] In various studies, to cover services, the population factor and response time have been used to provide timely services for the development of air relief bases.^[13,14,22] In a study, Røislien *et al.* found that 96.9% of the population were covered with air ambulance and 91.86% of accidents were covered with air ambulance in the first 45 min after the accident.^[22] In Røislien *et al.*, 90% of the population were covered with four bases for 45 min. To cover 100% of the population, nine air ambulance bases were needed.^[14] In the study by Erdemir *et al.*, instead of focusing to provide services to traffic accidents, they considered all types of emergency situations in the area.^[28] By adding additional bases, better coverage can be provided and lead to better services at a lower cost than adding trauma

centers.^[30] In the study of Flanigan *et al.*, there was a strong correlation between air ambulance coverage and reduced mortality.^[31]

Conclusion

There are few studies on effective factors in the development of air ambulance bases. Most studies have concentrated on quantitative factors including time, distance, covered population, cost, and high accident risk points. There are few qualitative studies in this regard. It is necessary to apply multidimensional models to consider various factors for development. Given the development of highly populated cities, events and ceremonies with a crowd of participants, and increase in human-made disasters, provision of these services is increasingly demanded.

Acknowledgment

This study is the result of the dissertation of the PhD in the School of Public Health and Safety, Shahid Beheshti University of Medical Sciences, Tehran, Iran. The current study was approved by the Ethics Committee School of Public Health and Neuroscience Research Center of Shahid Beheshti University of Medical Sciences, Tehran, Iran, with the ethical code (IR.SBMU.PHNS.REC.1398.075).

Financial support and sponsorship

This study was supported both financially and officially by Shahid Beheshti University of Medical Sciences with the code of Ethics: IR.SBMU.PHNS.REC.1398.075).

Conflicts of interest

There are no conflicts of interest.

References

1. Gräsner JT, Lefering R, Koster RW, Masterson S, Böttiger BW, Herlitz J, *et al.* EuReCa ONE, 27 nations, ONE Europe, ONRegistry: A prospective one month analysis of out-of-hospital cardiac arrest outcomes in 27 countries in Europe. *Resuscitation* 2016;105:188-95.
2. Earnest A, Hock Ong ME, Shahidah N, Min Ng W, Foo C, Nott DJ. Spatial analysis of ambulance response times related to prehospital cardiac arrests in the city-state of Singapore. *Prehosp Emerg Care* 2012;16:256-65.
3. Oliver GJ, Walter DP, Redmond AD. Prehospital deaths from trauma: Are injuries survivable and do bystanders help? *Injury* 2017;8:985-99.
4. Safi Keykaleh M, Sohrabzadeh S. The Emergency Medical System (EMS) response to Iraqi pilgrims' bus crash in Iran: A case report. *BMC Emerg Med* 2019;19:38.
5. Isakov A. Urgent air-medical transport: Right patient, place and time. *CMAJ* 2009;181:569-70.
6. Kalantari Meibodi M., Alamdari SH., Mohammadi P., Kariman H. 2010 [Last cited on 2021 Mar 26]; 1(4):48-52. Available from: <https://www.sid.ir/en/journal/ViewPaper.aspx?id=203191>, [In Persian].
7. Taylor CB, Stevenson M, Jan S, Middleton PM, Fitzharris M, Myburgh JA. A systematic review of the costs and benefits of

- helicopter emergency medical services. *Injury Prev* 2010;41:10-20.
8. Ahmadi-Javid A, Seyedi P, Syam SS. A survey of healthcare facility location. *Comput Oper Res* 2017;79:223-63.
 9. Shahbandar Zadeh H, Jamali G R, Mansouri M. Hierarchical location-allocation for emergency medical services. *Emergency Management*, 2015;4(1):57-86.
 10. Rajagopalan H, Sadam C, Xiao J. "A Multiperiod Set Covering Location Model for Dynamic Redeployment of Ambulances," *Computers & Operations Research* 2008;35:814-26.
 11. Araz CS, Ozkarahan I. A fuzzy multi-objective covering-based vehicle location model for emergency services. *Comput Oper Res* 2007;34:705-26.
 12. Wen MI. Facility location-allocation problem in random fuzzy environment: Using (α, β) - Cost minimization model under the Hurewicz criterion. *Comput Math Appl* 2008;55:704-13.
 13. Garner AA, van den Berg PL. Locating helicopter emergency medical service bases to optimise population coverage versus average response time. *BMC Emerg Med* 2017;17:31.
 14. Røislien J, van den Berg PL, Lindner T, Zakariassen E, Aardal K, van Essen JT. Exploring optimal air ambulance base locations in Norway using advanced mathematical modelling. *Inj Prev* 2017;23:10-5.
 15. Aghajani MS, Kolivand PH, Saberinia A, Noori H, Sarvar M. *Development Air Ambulance*. Tehran: Ministry of Health and Medical Education; 2016.
 16. appinen J, Olkinuora A, Laukkanen-Nevala P. Defining a mission-based method to determine a HEMS unit's actual service area. *Scand J Trauma Resusc Emerg Med* 2019;27:63.
 17. van den Berg PL, Fiskerstrand P, Aardal K, Einerkjær J, Thoresen T, Røislien J. Improving ambulance coverage in a mixed urban-rural region in Norway using mathematical modeling. *PLoS One* 2019;14:e0215385.
 18. Miller M, Delroy-Buelles I, Bootland D, Lyon RM. A Spatial Analysis of Incident Location and Prehospital Mortality for Two United Kingdom Helicopter Emergency Medical Services (HEMS). *Appl Spatial Analysis* 2020;13:575-90. <https://doi.org/10.1007/s12061-019-09318-2>
 19. Sorani M, Tourani S, Khankeh HR, Panahi S. Challenges of helicopter emergency medical service: A qualitative content analysis in Iranian context. *Health Policy Technol* 2018;7:374-8.
 20. Firouzi Jahantigh F, Ghaderi M. Location of the aerial ambulances using combination of fuzzy ANP and fuzzy dematel in the environment of ArcGIS: A case study in sistán and baluchestan province. *JHOSP* 2018;17:33-47.
 21. Navazi F, Tavakkoli-Moghaddam R, Sazvar Z. A multi-period location-allocation-inventory problem for ambulance and helicopter ambulance stations: robust possibilistic approach. *IFAC PapersOnLine* 2018;51:322-7.
 22. Røislien J, van den Berg PL, Lindner T, Zakariassen E, Uleberg O, Aardal K, et al. Comparing population and incident data for optimal air ambulance base locations in Norway. *Scand J Trauma Resusc Emerg Med* 2018;26:42.
 23. Shahriari M, Bozorgi-Amiri A, Tavakoli S, Yousefi-Babadi A. Bi-objective approach for placing ground and air ambulance base and helipad locations in order to optimize EMS response. *Am J Emerg Med* 2017;35:1873-81.
 24. Bozorgi-Amiri A, Tavakoli S, Mirzaeipour H, Ra-bani M, Integrated locating of helicopter stations and helipads for wounded trans-fer under demand location uncertainty, *American Journal of Emergency Medicine* (2016), doi: 10.1016/j.ajem.2016.11.024
 25. Hassani SA, Moharari RS, Sarvar M, Nejati A, Khashayar P. Helicopter emergency medical service in Tehran, Iran: A descriptive study. *Air Med J* 2012;31:294-7. [In Persian].
 26. Nishikawa W, Yamano Y. An overview of the development of helicopter emergency medical services in Japan. *Air Med J* 2010;29:288-91.
 27. Struck MF, Weber S. The Historical Development of Helicopter Emergency Medical Services in the German Democratic Republic. *Air Medical Journal*. 2010;29(6):294-9.
 28. Erdemir ET, Batta R, Rogerson PA, Blatt A, Flanigan M. Joint ground and air emergency medical services coverage models: A greedy heuristic solution approach. *Eur J Oper Res* 2010;207:736-49.
 29. Schuurman N, Bell NJ, L'Heureux R, Hameed SM. Modelling optimal location for pre-hospital helicopter emergency medical services. *BMC Emerg Med* 2009;9:6.
 30. Erdemir ET, Batta R, Spielman S, Rogerson PA, Blatt A, Flanigan M. Optimization of aeromedical base locations in New Mexico using a model that considers crash nodes and paths. *Accid Anal Prev* 2008;40:1105-14.
 31. Flanigan M, Blatt A, Lombardo L, Mancuso D, Miller M, Wiles D, et al. Assessment of air medical coverage using the Atlas and Database of Air Medical Services and correlations with reduced highway fatality rates. *Air Med J* 2005;24:151-63.
 32. Heggstad T, Børsheim KY. Accessibility and distribution of the Norwegian National Air Emergency Service: 1988-1998. *Air Med J* 2002;21:39-45.
 33. Clark DE, Hahn DR, Hall RW, Quaker RE. Optimal location for a helicopter in a rural trauma system: Prediction using discrete-event computer simulation. *Proc Annu Symp Comput Appl Med Care* 1994;:888-92.
 34. Judge T. HEMS: Luxury or necessity? *Air Med J* 2007;26:256-8.
 35. Boyd DD, Macchiarella ND. Occupant injury severity and accident causes in helicopter emergency medical services (1983-2014). *Aerosp Med Hum Perform* 2016;87:26-31.
 36. Sarvar M, Parvaneh E, Soltani D, Seyedzadeh M, Malhagh A. *Landing Zone Officer and Helicopter zone Officer in Operation HEMS*. Tehran: National Emergency Organization; 2016.
 37. Civil Aviat Authority UK's. Standards for helicopter landing areas at hospitals. The UK's specialist aviation regulator (UK's):Civil Aviat Authority 2016.
 38. Aghajani M, Shahrami A, Kolivand P, Saberinia A, Masoumi G, Sarvar M. Check the Program Upgrading the Air Emergency Services in the Health Transformation Plan: A Review of the Background, Necessity, Results and Challenges. *Hakim Research Journal* 20:175-85.
 39. Rasmussen K, Røislien J, Sollid SJ. Does medical staffing influence perceived safety? An international survey on medical crew models in helicopter emergency medical services. *Air Med J* 2018;37:29-36.
 40. Miller JO, Thammasitboon S, Hsu DC, Shah MI, Minard CG, Graf JM. Continuing medical education for air medical providers: The successes and challenges. *Pediatr Emerg Care* 2016;32:87-92.
 41. Bjørnsen LP, Solheim AM, Uleberg O, Skogvoll E. Compliance with a national standard by norwegian helicopter emergency physicians. *Air Med J* 2018;37:46-50.
 42. Association of Anaesthetists of Great Britain and Ireland Safety Guideline. Pre-hospital Anaesthesia. 2009. Available from: https://www.aagbi.org/sites/default/files/prehospital_glossy09.pdf. [Last accessed on 2015 Oct 15].
 43. Knotts D, Arthur AO, Holder P, Herrington T, Thomas SH. Pneumothorax volume expansion in helicopter emergency medical services transport. *Air Med J* 2013;32:138-43.
 44. Marinangeli FT, Ursini ML, Ricotti V, Varrassi G. Helicopter emergency medical service in Italy: Reality and perspective. *Air Med J* 2007;6:292-8.
 45. Den Hartog D, Romeo J, Ringburg AN, Verhofstad MH, Van Lieshout EM. Survival benefit of physician-staffed Helicopter Emergency Medical Services (HEMS) assistance for severely injured patients. *Injury* 2015;46:1281-6.
 46. Sahebi A, Ghomian Z, Sarvar M. Helicopter emergency medical services in 2017 Kermanshah earthquake; a qualitative study. *Arch Acad Emerg Med* 2019;7:e31.

47. Brown JB, Gestring ML, Guyette FX, Rosengart MR, Stassen NA, Forsythe RM, *et al.* Helicopter transport improves survival following injury in the absence of a time-saving advantage. *Surgery* 2016;159:947-59.
48. Brown JB, Gestring ML, Guyette FX, Rosengart MR, Stassen NA, Forsythe RM, *et al.* External validation of the Air Medical Prehospital Triage score for identifying trauma patients likely to benefit from scene helicopter transport. *J Trauma Acute Care Surg* 2017;82:270-9.
49. Adam Chesters PH, Timothy J. Hodgetts perceptions and culture of safety among helicopter emergency medical service personnel in the UK. *Emerg Med J* 2016;33:801-6.
50. Baker SP, Grabowski JG, Dodd RS, Shanahan DF, Lamb MW, Li GH. EMS helicopter crashes: What influences fatal outcome? *Ann Emerg Med* 2006;47:351-6.
51. Boyd, Douglas D, Macchiarella, Nickolas D. Occupant injury severity and accident causes in helicopter emergency medical services. *Aerospace medicine and human performance*. 2016;87(1):26-31.
52. Winn WT. HEMS simulator training for safety and clinical proficiency. *Air Med J* 2010;29:300-3.
53. Ringburg AN, de Ronde G, Thomas SH, van Lieshout EM, Patka P, Schipper IB. Validity of helicopter emergency medical services dispatch criteria for traumatic injuries: A systematic review. *Prehosp Emerg Care* 2009;13:28-36.
54. Thomson DP TS. Guidelines for air medical dispatch. *Prehosp Emerg Care*. 2003;7:265-71.
55. Fattahi PH, Chobtashan M, Sepehri M. Modeling and solving the problem of locating ambulance stations, a review study. In: 12th International Industrial Engineering Conference 2015. <https://civilica.com/doc/516137>.
56. Wilde ET. Do emergency medical system response times matter for health outcomes? *Health Econ* 2013;22:790-806.
57. Jalali A *Vital Supports: Basic, Advanced*. Tehran: 30ostad; 2006. [In Persian].
58. Bryan E . Bledose RSp, Richard A . Chery MS EMT - P. *Intermediate emergency care: principles & practice*. Tehran 2007.
59. Samuel M, Galvagno DO Jr. *Helicopter Emergency Medical Services for Adults With Major Trauma*. Baltimore, Maryland: Johns Hopkins University; 2012.
60. Sullivent EE, Faul M, Wald MM. Reduced mortality in injured adults transported by helicopter emergency medical services. *Prehosp Emerg Care* 2011;15:295-302.
61. Weinstein MC, Siegel JE, Gold MR, Kamlet MS, Russell LB. Recommendations of the panel on cost-effectiveness in health and medicine. *JAMA Surg* 1996;276:1253-8.
62. Sánchez-Mangas R, García-Ferrer A, de Juan A, Arroyo AM. The probability of death in road traffic accidents. How important is a quick medical response? *Accid Anal Prev* 2010;42:1048-56.
63. Goli, A , Gholinaghian, M, Rafiei, F . Multi-detection location and routing of rescue vehicles in crises with the purpose of reducing relief times using covered tour approach and random simulation. In: 12th International Industrial Engineering Conference. 2015. <https://civilica.com/doc/516011>.
64. Demetriades D, Kimbrell B, Salim A, Velmahos G, Rhee P, Preston C, *et al.* Trauma deaths in a mature urban trauma system: is "Trimodal" distribution a valid concept? *J Am Coll Surg* 2005;201:343-8.
65. *Global status report on road safety 2018*. Geneva: World Health Organization; 2018. Licence: CC BY-NC-SA 3.0 IGO.
66. Vijai MN, Ravi P R , Pathania A. Critical care air transport: Experiences of a decade. *JMR* 2018;4:53-8.
67. Spano SJ, Campagne D, Stroh G, Shalit M. A lightning multiple casualty incident in Sequoia and Kings Canyon National Parks. *Wilderness Environ Med* 2015;26:43-53.
68. Bloch YH, Schwartz D, Pinkert M, Blumenfeld A, Avinoam S, Hevion G, *et al.* Distribution of casualties in a mass-casualty incident with three local hospitals in the periphery of a densely populated area: Lessons learned from the medical management of a terrorist attack. *Prehosp Disaster Med* 2007;22:186-92.
69. McGregor J, Hanlon N, Emmons S, Voaklander D, Kelly K. If all ambulances could fly: Putting provincial standards of emergency care access to the test in Northern British Columbia. *Can J Rural Med* 2005;10:163-8.