



## Cost-effectiveness Analysis of Air Emergency Versus Ground Emergency Medical Services Regarding the Patient's Transportation and Treatment in Selected Hospital

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### Abstract

**Background:** The prehospital emergency system is the first initiator of medical care as an alternative to hospitals and health care services that helps patients and injured people in critical situations and accidents. This study aimed to evaluate the cost-effectiveness of air ambulance versus ground ambulance regarding the patient's transportation and treatment.

**Methods:** In this cost-effectiveness analysis study, 300 patients who were transferred to the Shohadaye HaftomTir hospital by air ambulance and 300 patients transferred by ground ambulance during the study period were selected in 2021-2022. This study examined the costs from the society's perspective. After drawing the decision tree model in TreeAge software, the incremental cost-effectiveness ratio was calculated; and to evaluate the strength of the analysis results, one-way and two-way sensitivity analyses were done on all costs and consequence parameters.

**Results:** The effectiveness rate in the ground ambulance group and in the air ambulance group was 0.42591 and 0.5566, respectively, and the total cost of transportation and treatment by ambulance in these patients was \$412.88 and for patients transported and treated by air ambulance was \$11898.05. Therefore, air ambulance costs more and is more effective than ground ambulance, and the amount of incremental cost and effectiveness of air ambulance compared with ground ambulance was \$11485.17 and 0.130773 units, respectively. The incremental cost-effectiveness ratio (ICER) of the 2 strategies was 87825.28, and the cost-effectiveness threshold was \$7200. To determine the strength of the study results, one-way and two-way sensitivity analyses were done and the results of the cost-effectiveness analysis was not changed.

**Conclusion:** Our study showed that ground ambulance is more cost-effective than air ambulance and the most important reason is that the total cost of air ambulance is 26 times more than ground ambulance, however, it is more effective than ground ambulance.

**Keywords:** Cost-Effectiveness, Air Emergency, Ambulance

**Conflicts of Interest:** None declared

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### Introduction

One of the first basic steps in providing prehospital emergency services is the timely use of resources, for this purpose, the appropriate patient should be transferred to

the appropriate medical center and make the best possible use of time. Professionals in the prehospital emergency department may be dispatched to the scene of the accident

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#### ↑What is "already known" in this topic:

The air emergency is an essential need in providing health services in distant areas which ensures that there is access to health services outside of hospitals.

#### →What this article adds:

Ground ambulance is more cost-effective than air ambulance and the most important reason is that the total cost of air ambulance is 26 times more than ground ambulance, however, it is more effective than ground ambulance.

or to the patient's location in a variety of ways, depending on the patient's condition, the location of the accident, and the patient's location (1, 2). In many countries, the air emergency is an essential need in providing health services in distant areas that ensures that there is access to health services outside of hospitals and the air emergency service transfers the patient at the right time directly to the appropriate level of care (3, 4).

The air ambulance has been operating in Iran since 2000. Before the health system transformation plan, a limited number of air ambulances were serving in the country. After that plan, considering that one of the goals was the air ambulance and increasing access to it, more than 30 air ambulances were added to the country's emergency air system. In 2018, a total of 22,495 patients were transferred to hospitals via the air ambulance, which was one of the important reasons for the decrease in the mortality rate of pregnant women in deprived areas. The benefits of an air emergency system are highly dependent on the access time, which consists of the accident time to the arrival time of the emergency team at the scene, the arrival time at the hospital, and continuing the treatment (1).

The air emergency service in trauma patients or patients with acute medical conditions serves in 2 ways, either by attending to the accident scene to examine trauma patients (5) and acting as the first responder to the emergent case or acting as the secondary responder after the ambulance's technicians examine the patient, when the air ambulance transports patients to the hospital (6-8). The transfer of patients by the air emergency service can reduce the transfer to hospital time considerably, which is because of high speed, no road traffic, and other road conditions, and this reduction in time is very useful in distant areas or patients requiring immediate interventions, such as cardiovascular catheterization and stroke interventions. However, the transfer of patients to the hospital via the air emergency service is not always fast due to delays from request to the start time of flight, preparation, time of flight to the arrival at the scene, and the time of arrival at the hospital. Therefore, it is necessary to evaluate different ways for patient transfer (9-11).

One of the most important methods of evaluating different approaches to health interventions is cost-effectiveness analysis (CEA). The cost effectiveness analysis is one type of economic evaluation that compares the costs and effectiveness of alternative interventions in health care. This approach focuses on assessing the intervention's impact on clinical measures, unlike other types of economic evaluation that consider broader effects (12, 13).

Since providing care via the air emergency service leads to an increase in costs, such care will not be away from cost-benefit analysis and the benefits of these services will be assessed (1, 3). Many studies have investigated the cost-effectiveness of various systems. In the United States, studying more than 5000 patients showed that the pre-hospital emergency system helps reduce the mortality of patients by up to 15%, however, to be more cost-effective, the transfer of patients with minor injuries should be revised (14). A study in the United States compared air am-

bulance versus ground ambulance in patients with spinal cord injury and found that although the air ambulance had a lower mean time, the way of transfer did not differ in having more injury, and finally they concluded that this service should be continued according to the general demand (15). Other findings have shown that since the use of the air emergency service can increase patient survival, saving people's lives can be the main reason for its cost-effectiveness (16). Therefore, considering the cost of the air emergency service in Iran and its improvement in the health system transformation plan, in this study, we investigated the cost-effectiveness of the air emergency service compared with the ground ambulance from 2017 to 2019.

## Methods

This study is one of the quantitative and cost-effectiveness analysis studies that used the decision tree model to investigate the cost-effectiveness of the air emergency service compared with the ground ambulance. In this study, 300 patients who were transferred to the Shohadaye Haftom Tir hospital in 2021-2022 by the air emergency service were selected and examined (n = 324). Because of the incomplete medical records of some of the patients, 8% of patients were eliminated and 300 records entered the study; and for ambulance strategy 300 patients were selected. To prevent selection bias, we selected ground ambulance patients who matched with air ambulance patients in terms of age group and type of injury. Finally, 600 patients with different types of traumas were included in the study, and cost-effectiveness analysis was performed on them.

In both groups, patients had severe and moderate trauma, based on the MGAP criteria (mechanism of injury, GCS, age, and systolic blood pressure) as inclusion criteria. Based on the severity of injuries, the ambulance group's patients were matched with those of the air emergency group.

In this study, the criterion for calculating costs was according to the society's perspective, which includes direct medical costs, nonmedical direct costs, and indirect costs. Direct costs were divided into medical costs, including patient transportation, hospital admission, outpatient visit, and medication use, and nonmedical costs, including family and other companions of the patient transportation and caregiver costs. Indirect costs from lost productivity, either from the use of health care service or premature death, were analyzed as clinical data and costs were extracted from the Tehran Emergency System Center, the treatment department of Iran University of Medical Sciences, and Shohadaye HaftomTir hospital. The effectiveness indicators studied in this model include the relative risk of mortality, the survival rate of patients 1 year after discharge from the hospital, and the patients' QoL. To assess the QoL, the EQ5D questionnaire and the VAS index were used that have been already evaluated and used in national and international studies (17-19). In this study, utility was considered as an indicator of measurement of QoL. The "utility" of health status is usually expressed on a numeric scale from 0 to 1, where 0 represents the "utility" of the "dead" state and 1 the "utility" of the

experienced state in "perfect health." The utilities assigned to a specific state of health can be estimated using a series of techniques such as Standard Gamble, Time Trade-Off or Rating Scale, or by means of prescored health state sorting systems (18, 20). We used a decision tree model for all participants of different ages with moderate and severe trauma to analyze the cost and effectiveness of the two groups from patient injury to hospital arrival, hospitalization and 1 year after release, and ultimately based on this evidence came up with the most cost-effective strategy. The main purpose of using the decision tree model is to choose the best decision from at least 2 possible options at the time of making decisions using the available information. According to Inadomi, the main functions of decision-making analysis and cost-effectiveness analysis are to provide a qualitative summary of available data and to hypothesize for further researches (21). After drawing the decision tree model in the TreeAge Pro 2011 software, the incremental cost-effectiveness ratio, which is defined by the difference in cost divided by the difference in the effect, was calculated. If the incremental cost-effectiveness ratio is negative, one of the programs is cost-effective compared with the other, and if it is positive, to make a decision, this ratio must be compared with the threshold. The World Health Organization method was used to calculate the threshold. If the incremental cost-effectiveness ratio is less than 3 times the country's annual gross domestic product (GDP) per capita, the program is cost-effective (22). Also, to evaluate the strength of the analysis results in this study, we used one-way and two-way sensitivity analysis on all cost and consequence parameters.

## Results

According to Table 1, 75% of patients in the air emergency service and 70% in the ambulance group were men. Also, 18% of air emergency service patients and 30% of ground ambulance patients were women. It should be not-

ed that in the air emergency group 7% of the patients were registered as unknown and their gender was not specified. Moreover, in the air emergency group, most patients were in the age groups of 20 to 30 and 30 to 40 years, respectively, and few patients were in the 70-90 years group. In the ground ambulance group, the majority of patients were in the age group of 20-30 years and only a few were in the age group of 80-90 years.

As shown in Table 2, the direct medical costs, direct nonmedical costs, and indirect costs in the ground ambulance group were 78%, 4%, and 18% of the total costs, respectively, and in the air emergency group, they were 81%, 3%, and 16%, respectively. In general, the percentage of direct medical costs, nonmedical direct costs, and indirect costs for both ways of transport and treatment of patients were 79.5%, 3.5%, and 17%, respectively. In the ground ambulance and air emergency group, the QoL of patients were 48% and 63%, the survival rates were 63% and 89%, and the mortality rates were 10% and 13%, respectively.

## Cost-effectiveness

As shown in Table 3 and Figure 1, the effectiveness rate in the ground ambulance group and in the air emergency was 0.42591 and 0.5566, respectively, and the total cost of transportation and treatment by the ambulance in these patients was \$412.88 and for patients transported and treated by the air ambulance was \$11898.05. Therefore, the air emergency service is more expensive and more effective than the ground ambulance, and the amount of incremental cost of the air emergency service compared to the ground ambulance was \$11485.17 and the amount of incremental effectiveness was 0.130773 units. The incremental cost-effectiveness ratio (ICER) of the 2 strategies was 87825.28, the mean cost-effectiveness of the ambulance was 969.40 and for the air emergency service was 21373.14. Therefore, the marginal value of the air emergency service compared to the ground ambulance in these

Table 1. Demographic characteristics of the participants

Strategy	Ambulance		Air Emergency	
Age group and gender	Percent	Frequency	Percent	Frequency
Gender (male)	70	210	75	225
0-10	10	28	11	33
10-20	11	28	10	30
20-30	25	74	27	82
30-40	23	62	24	71
40-50	11	30	11	34
50-60	8	23	6	19
60-70	6	18	6	19
70-80	4	11	2	7
80-90	2	7	2	5
Total	100	300	100	300

Table 2. Cost and effectiveness dimensions of patient transfer and treatment

Strategy	Direct Medical cost	Direct Nonmedical Cost	Indirect Cost	Total Costs (\$)	Mor <sup>1</sup>	QoL	Sur <sup>2</sup>
Ambulance	322.04 78%	16.51 4%	78.31 18%	412.88	10%	48%	63%
Air emergency	9637.42 81%	356.94 3%	1903.68 16%	11898.05	13%	63%	89%
Total	9787.18 79.5%	430.88 3.5%	2092.85 17%	12310.93			

<sup>1</sup> Mor: Mortality, <sup>2</sup> Sur: Survival

## Cost-effectiveness Analysis of Air Emergency Versus Ground Emergency

Table 3. Cost-effectiveness of air emergency vs ground ambulance

Strategy Name	Effectiveness	Cost	Marginal Value	Incremental Effectiveness	Incremental Cost	Incremental Cost-effectiveness	Mean Cost-effectiveness	Expected Value
Ambulance	0.42591	412.88	0	0	0	0	969.40	969.40
Air emergency	0.556683	11898.05	87825.27	0.130773	11485.17	87825.28	21373.14	21373.14

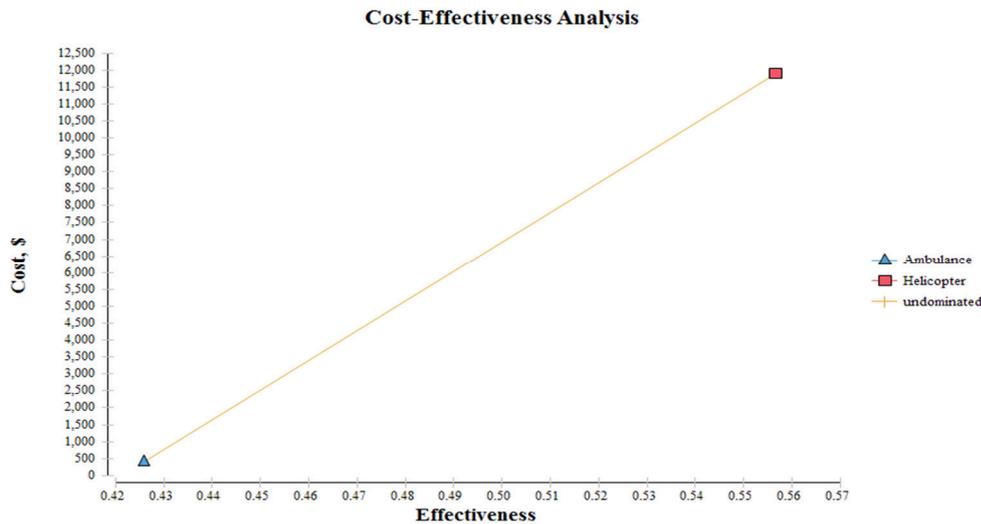


Fig. 1. Cost-effectiveness graph

patients was 87825.27 and the expected value in the ambulance was 969.40 and in the air emergency service was 21373.14.

### Sensitivity Analysis

To evaluate the strength of study results, all cost and consequence data were selected and sensitivity analysis,

using the Tornado model (Fig. 2), 1-way and 2-way sensitivity analysis, was performed.

**One-Way Sensitivity Analysis:** In the 1-way sensitivity analysis (Table 4), using the results of the Tornado analysis, the parameter that had the greatest impact (total cost of air emergency service) on the study result was selected, thus, finally it was revealed that by performing this sensi-

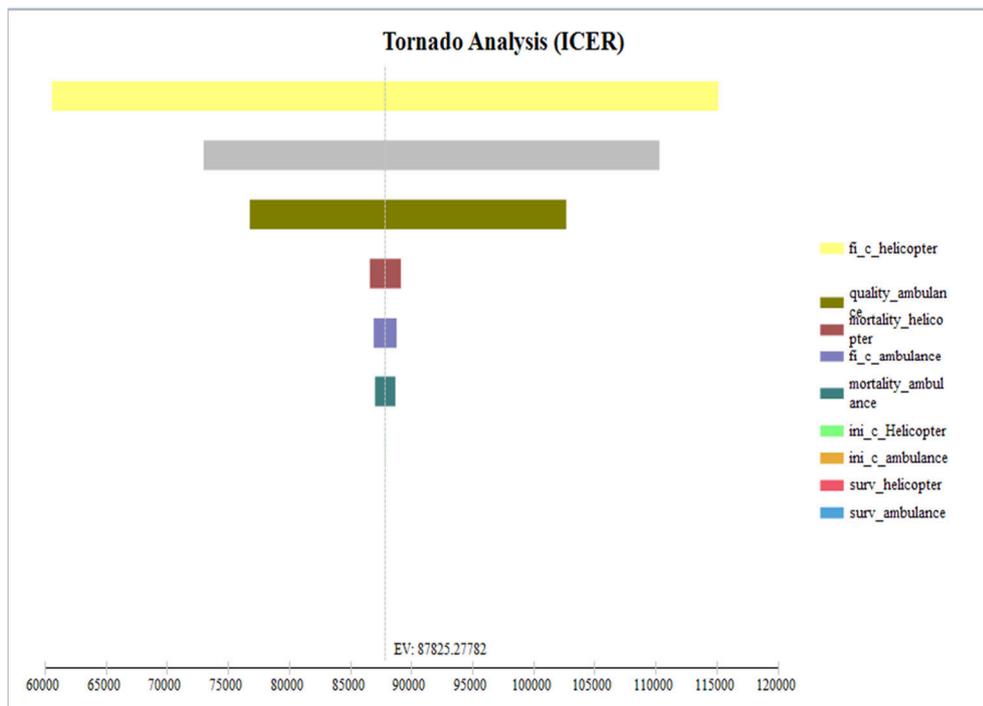


Fig. 2. Tornado model for sensitivity analysis of parameters

tivity analysis the results of cost-effectiveness analysis were not changed.

**Two-Way Sensitivity Analysis:** In the 2-way sensitivity analysis, the 2 parameters (total cost of air emergency service and QoL in air emergency strategy) that had the most impact on the results of the analysis according to the Tornado diagram were selected and their values were changed based on the  $\pm 30\%$  of the base value for cost and  $\pm 10\%$  of base value for effectiveness indicator and then the effects of these changes on the analyses were observed (Fig. 3).

As can be seen in Figure 3, by changing the parameters in

a specified range, the result of cost-effectiveness analysis has not changed.

## Discussion

In this study, we investigated the cost-effectiveness of the air emergency service compared to the ground ambulance in patients with various traumas, and first, we evaluated the effectiveness of 2 strategies. In the ambulance and air emergency groups, the QoL index of patients were 48% and 63%, the survival rates 63% and 89%, and the mortality rates 10% and 13%, respectively. Thus, according to the software output, the effectiveness rate in the

Table 4. One-way sensitivity analysis

Variable	Strategy	Cost	Eff	CE	IncrCost	Inceff	IncrCE
8403	Ambulance	412.8807	0.42591	969.4094	0	0	0
8403	Air Emergency	8332.47	0.55668	14968.08	7919.5893	0.13077	60559.82895
9123.3	Ambulance	412.8807	0.42591	969.4094	0	0	0
9123.3	Air Emergency	9045.567	0.55668	16249.06	8632.6863	0.13077	66012.76732
9843.6	Ambulance	412.8807	0.42591	969.4094	0	0	0
9843.6	Air Emergency	9758.664	0.55668	17530.04	9345.7833	0.13077	71465.70568
10563.9	Ambulance	412.8807	0.42591	969.4094	0	0	0
10563.9	Air Emergency	10471.76	0.55668	18811.01	10058.8803	0.13077	76918.64405
11284.2	Ambulance	412.8807	0.42591	969.4094	0	0	0
11284.2	Air Emergency	11184.86	0.55668	20091.99	10771.9773	0.13077	82371.58242
12004.5	Ambulance	412.8807	0.42591	969.4094	0	0	0
12004.5	Air Emergency	11897.96	0.55668	21372.96	11485.0743	0.13077	87824.52078
12724.8	Ambulance	412.8807	0.42591	969.4094	0	0	0
12724.8	Air Emergency	12611.05	0.55668	22653.94	12198.1713	0.13077	93277.45915
13445.1	Ambulance	412.8807	0.42591	969.4094	0	0	0
13445.1	Air Emergency	13324.15	0.55668	23934.92	12911.2683	0.13077	98730.39752
14165.4	Ambulance	412.8807	0.42591	969.4094	0	0	0
14165.4	Air Emergency	14037.25	0.55668	25215.89	13624.3653	0.13077	104183.3359
14885.7	Ambulance	412.8807	0.42591	969.4094	0	0	0
14885.7	Air Emergency	14750.34	0.55668	26496.87	14337.4623	0.13077	109636.2743
15606	Ambulance	412.8807	0.42591	969.4094	0	0	0
15606	Air Emergency	15463.44	0.55668	27777.84	15050.5593	0.13077	115089.2126

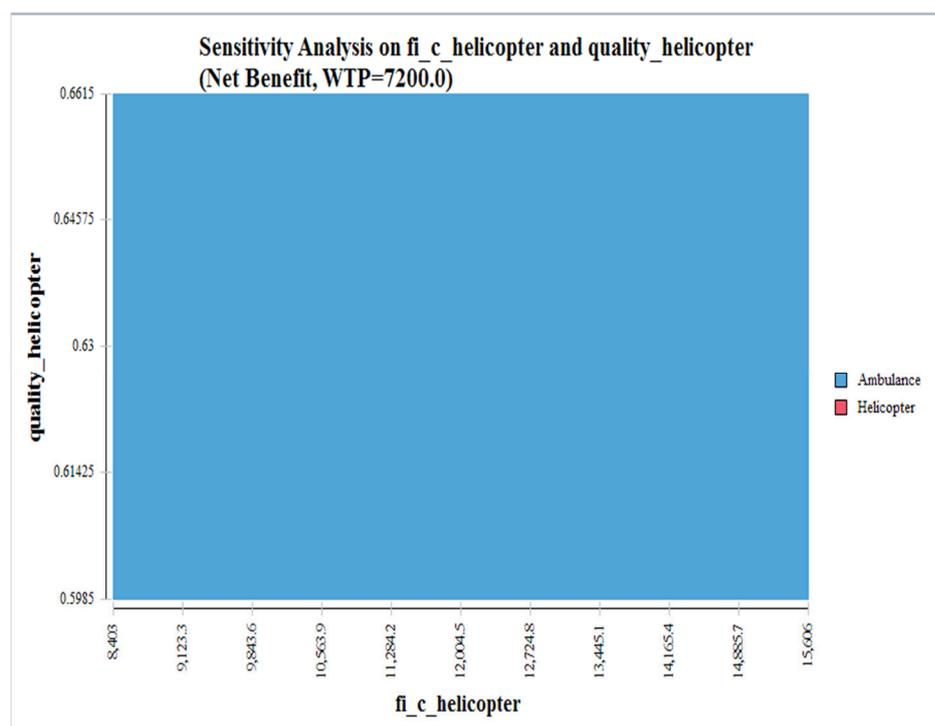


Fig. 3. Two-way sensitivity analysis

ambulance group and the air emergency group was 0.42591 and 0.5566, respectively, and it can be said that the air emergency service is more effective than the ground ambulance.

Regarding the cost-effectiveness of the air emergency service compared to the ground ambulance, it was found that the air emergency service was more expensive and more effective than the ground ambulance. The results of the sensitivity analysis also showed that the results were resistant to most variations in the model's assumptions, so the results of the cost-benefit analysis remained unchanged and the outpatient strategy is a cost-effective strategy. Browman et al found that the air emergency service reduced mortality by 23% to 32% in patients with severe injuries compared to the air ambulance, and since the cost of the air emergency transportation was as same as the ground ambulance, the air emergency service is more cost-effective than the ground ambulance (23, 24). In the present study, the cost of transporting patients by the air ambulance is much higher than ground ambulance, and this factor has caused the results of our study to be different from their study. Delgado et al reported that the air emergency service is cost-effective if it reduces mortality by at least 17% compared to the ground ambulance and has significant consequences on eliminating long-term disabilities. It was also revealed that a significant reduction in mild injuries could make the air emergency more cost-effective than the ground ambulance (14). Increasing the effectiveness and reducing the cost of air emergency are the key factors in choosing this strategy for transporting and treating patients, but these 2 factors do not always occur and this raises doubts in choosing the type of strategy, so that in our study, the increase in effectiveness was associated with an increase in costs so the reason for the difference between the results of previous studies and the present study is that the cost of transporting patients with the air emergency service in our country is almost 26 times higher than the ground ambulance and this indicates that the ground ambulance is more cost-effective than the air emergency service in our country. Therefore, reducing the cost of air ambulance in the field of patient transportation should be a priority for health system managers to provide the basis for the development of this strategy throughout the country so that patients with unstable and serious conditions could be transferred to medical centers in the shortest possible time to reduce patients' mortality rate. Due to the fact that accidents and trauma in Iran are the most common reason for requesting a rescue helicopter, the reduction of golden time after a trauma is involved in reducing mortality due to trauma. Using the necessary standards in rescue helicopters reduces mortality by reducing transit time. Also, due to the high cost of using a rescue helicopter, using a suitable algorithm to select patients, using telemedicine and completing standard equipment and drugs can help increase the efficiency of this type of ambulance.

A review study by Ringburg et al showed that the air emergency service on average saves 2.7 lives per 100 transfers (25). A study by Galvagno et al also found that the air emergency service increased patients' chances of

survival by 16% or saved 1.5 lives per 100 transfers in patients with severe injuries (26). These results are consistent with the findings of our study. The reason is the rapid arrival of air ambulance at the patient's bedside and the start of treatment interventions and, if necessary, a transfer to medical centers in the shortest possible time.

One of the main limitations of this study was the lack of a complete match between the 2 groups of patients according to the MGAP criteria. Due to defects in patients' records, based on this index, only injury mechanism and age were examined as inclusion criteria. Another limitation was the recall bias that patients who had previously been discharged were not fully aware of their QoL at the time of hospitalization. In such cases, researchers asked from the family member, with an 80% probability of accuracy. The most important strength of this study was that no such study has been conducted in Iran to date and very few studies have been conducted worldwide that have examined only the QoL index, but in this study, the 3 indicators of patient mortality rate, 1-year survival, and QoL were assessed. Due to the fact that the selected hospital was a trauma center in Iran, therefore the results of this study can be generalized to some extent to the research community.

### Conclusion

Our study showed that the ground ambulance is more cost-effective than the air ambulance and the most important reason is that the cost of air emergency service is 26 times more than the ground ambulance. Also, there is a hypothesis that the air ambulance can be more cost-effective than the ground ambulance when considering specific age groups, the type of injury, and the distance from the hospital. This was the first study conducted in Iran that has compared the cost-effectiveness of 2 strategies. Our study shows that the efficacy criteria examined by health care system administrators and policymakers influence the choice of patient transfer.

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### Conflict of Interests

The authors declare that they have no competing interests.

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