ORIGINAL CONTRIBUTIONS

REDUCED MORTALITY IN INJURED ADULTS TRANSPORTED BY HELICOPTER EMERGENCY MEDICAL SERVICES

Ernest E. Sullivent, MD, MPH, Mark Faul, PhD, MA, Marlena M. Wald, MPH, MLS

ABSTRACT

Background. Some studies have shown improved outcomes with helicopter emergency medical services (HEMS) transport, while others have not. Safety concerns and cost have prompted reevaluation of the widespread use of HEMS. **Objective.** To determine whether the mode of transport of trauma patients affects mortality. **Methods.** Data for 56,744 injured adults aged ≥18 years transported to 62 U.S. trauma centers by helicopter or ground ambulance were obtained from the National Sample Program of the 2007 National Trauma Data Bank. In-hospital mortality was calculated for different demographic and injury severity groups. Adjusted odds ratios (AOR) were produced by utilizing a logistic regression model measuring the association of mortality and type of transport, controlling for age, gender, and injury severity (Injury Severity Score [ISS] and Revised Trauma Score [RTS]). **Results.** The odds of death were 39% lower in those transported by HEMS compared with those transported by ground ambulance (AOR = 0.61, 95% confidence interval [CI] = 0.54–0.69). Among those aged ≥55 years, the odds of death were not significantly different (AOR = 0.92, 95% CI = 0.74–1.13). Among all transports, male patients had a higher odds of death (AOR = 1.23, 95% CI = 1.10–1.38) than female patients. The odds of death increased with each year of age (AOR = 1.040, 95% CI = 1.037–1.043) and each unit of ISS (AOR = 1.080, 95% CI = 1.075–1.084), and decreased with each unit of RTS (AOR = 0.46, 95% CI = 0.45–0.48). **Conclusion.** The use of HEMS for the transport of adult trauma patients was associated with reduced mortality for patients aged 18–54 years. In this study, HEMS did not improve mortality in adults aged ≥55 years. Identification of additional variables in the selection of those patients who will benefit from HEMS transport is expected to enhance this reduction in mortality. **Key words:** helicopter; mortality; National Trauma Data Bank; severity; transport

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INTRODUCTION

Injury is the leading cause of death in the United States for persons aged 1–44 years.[1] In 2006, injuries accounted for approximately 179,000 deaths in the United States.[2] In an effort to improve outcomes, the trauma and prehospital care communities have sought ways to decrease the elapsed time between injury and definitive care.[3] Helicopter emergency medical services (HEMS) were created and encouraged as a strategy to decrease this interval.[4]

The first formal helicopter ambulance program was initiated by the U.S. military during the Korean conflict (1950–1953), in which a small group of 12 helicopters conducted 20,000 transports. The majority of these reached Mobile Army Surgical Hospitals (MASH units) in less than 60 minutes after injury, which compared very favorably with the previous average of four to six hours for treatment for the wounded.[5] Helicopter ambulance use expanded in the Vietnam conflict (1962–1973), providing some 800,000 transports; the average time to treatment for those seriously injured was less than 60 minutes and the overall mortality rate for those transported by helicopter was only 2%.[6]

In 1972, the first U.S. privately funded hospital-based helicopter ambulance service was initiated at St. Anthony's Hospital in Denver.[7,8] By 1980, fewer than 50 aircraft were used for HEMS in the United States, and the total number of patients transported

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Address correspondence and reprint requests to: Mark Faul, PhD, MA, Centers for Disease Control and Prevention, National Center for Injury Prevention, 4770 Buford Highway, Atlanta, GA 30341. e-mail: mfaul@cdc.gov

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was 25,000.[9] Since that time, there has been a tremendous increase in the availability and use of HEMS; in 2007, there were 830 helicopters providing HEMS in the United States transporting more than 275,000 patients a year.[9]

Two advantages of HEMS are generally considered to be the shorter time interval from injury to definitive care (due to decreased response time and decreased transport time) and a higher level of expertise among the HEMS prehospital providers.[10,11] The disadvantages of HEMS include higher costs and the inherent risks of helicopter travel. Recent increases in medical helicopter crashes[9] and a recent high-profile multifatality crash in Maryland involving patients who may not have been severely injured have intensified the debate over the benefit of this service.[12]

Helicopter EMS has been found to be cost-effective in trauma patient treatment if there is a substantial survival benefit with its use, and the magnitude of this benefit is the most important factor in determining cost-effectiveness.[13] Given the costs and risks associated with helicopter transport of trauma patients, it is critical to determine whether there are clear medical benefits from HEMS. Reports to date have not consistently demonstrated outcome benefit in the use of HEMS. Although most previous studies have examined the relationship between the mode of transport of trauma patients and outcome in local and regional systems, few studies have explored the impact of HEMS on a national level. This study was conducted to determine whether the mode of transport of trauma patients affects mortality.

METHODS

Sample

This study examined aggregate 2007 National Sample Program (NSP) data from the National Trauma Data Bank (NTDB), which is maintained by the American College of Surgeons–Committee on Trauma (ACS-COT) with support from the Centers for Disease Control and Prevention (CDC). The NTDB is the largest aggregation of U.S. trauma registry data assembled.[14] The NTDB data sets contain demographic data, prehospital information, anatomic injury data, physiologic variables recorded by emergency medical services (EMS) and the emergency department (ED), and other variables. The NTDB data sets contain no personal identifiers. The NTDB NSP data set contains information on up to 100 randomly selected trauma centers in an attempt to provide national estimates for adult patients seen in level I and II trauma centers.[15] The 2007 NSP data set contained 148,270 records of patients with valid trauma diagnoses treated at 82 participating trauma centers.

Identifying Relevant Records

Isolating the potential impact of helicopter transportation compared with ground transportation led to record exclusion (Fig. 1). Only 2007 injury records were used. Fixed-wing (airplane) transports and all other types of transports and methods of arrival were excluded (e.g., walk-in, private vehicle, public transportation, law enforcement). Only those patients transported directly to the trauma center from the injury scene were included. Interfacility transfers, which may account for a large proportion of all HEMS flights in some settings,[16] were excluded. Injured patients aged <18 years were excluded. Records from seven facilities that had only ground transports and no helicopter transports were excluded because these facilities could not provide any variance on the transport variable in the model.

Records with missing age, gender, Injury Severity Score (ISS), or transport mode were excluded from the study. Emergency medical services records were used to provide physiologic data necessary for our calculation of the Revised Trauma Score (RTS) (i.e., Glasgow Coma Scale [GCS] score, systolic blood pressure [SBP], and respiratory rate [RR]) for each patient. If data for one or more of these three variables were missing, ED physiologic data were used. Assuming that trauma centers with a higher percentage of complete records would provide a more accurate sample, only records from facilities in which ≥80% of the patients had all three RTS physiologic data were included in the study. The final data set included records for 56,744 injured adults transported to 62 U.S. trauma centers (76% of the trauma centers contributing to the NTDB NSP).

Measures

Data were analyzed for each patient using demographic, clinical, and EMS transport mode variables. The demographic variables selected were age and gender. The clinical variables included the ISS and the three components of the RTS (GCS score, SBP, and RR). The EMS transport mode variable was classified as either helicopter or ground transport. The outcome variable for this study was in-hospital mortality, which was defined as death after arrival to the ED but before discharge from the hospital during the same admission.

The ISS is an anatomically based ordinal scale with a range from 1 (minimal injury) to 75 (maximal injury).[17] To compute the ISS, first a score of 1 to 6 (higher score for more severe injury) is assigned for injuries to each of six body regions: head/neck, face, thorax, abdomen/visceral pelvis, bony pelvis/extremities, and external structures. The total score is then calculated as the sum of the squares of the highest scores in each of the three most severely injured body regions. The ISS

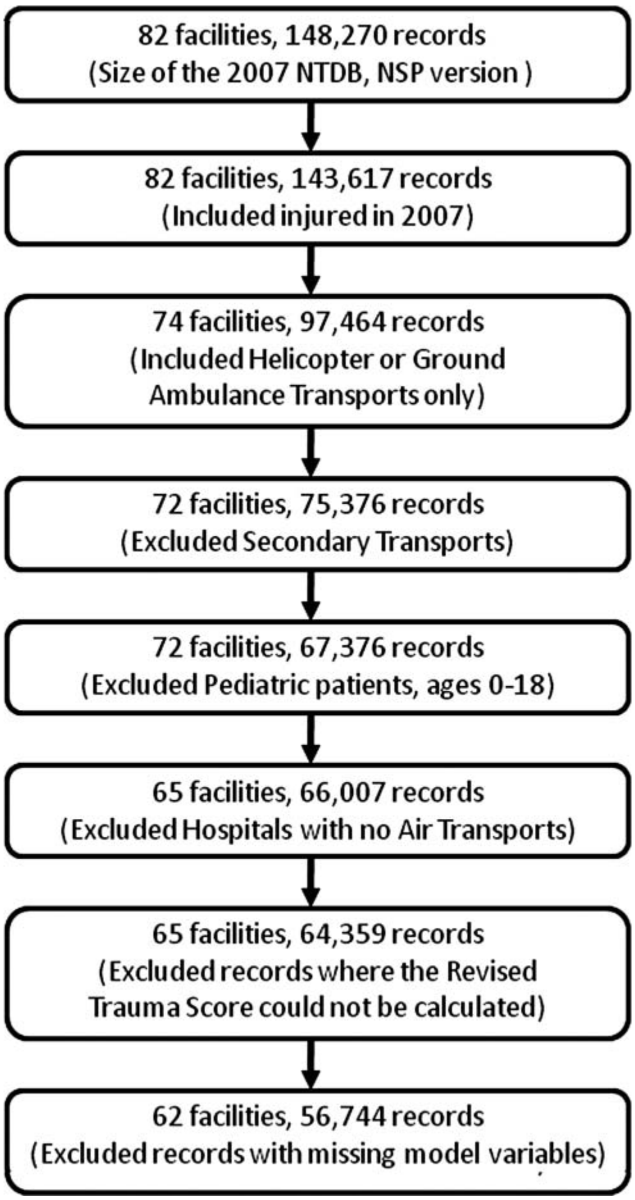

FIGURE 1. Study population: National Trauma Data Bank (NTDB) National Sample Program (NSP), 2007.

has been used to predict mortality, morbidity,[18,19] and risk for postinjury multiple organ failure.[20] In trauma research, the ISS also has been used to dichotomize trauma patients into severe injuries (ISS ≥15) and nonsevere injuries (ISS <15) and to evaluate the outcomes of patients with similar degrees of injury severity.[21,22]

To more closely correspond with outcome, a physiologic injury severity scoring system such as the RTS was used in addition to the anatomic classification of injury severity. The RTS has been shown to be associated with survivability and is used in trauma research for outcome evaluations and to control for injury.[23] Each of the three variables of the RTS is assigned a score between 0 and 4. By definition, the first set of data recorded for the patient (i.e., ED data if EMS data are not available) is used for the calculation of the RTS. Established weights are applied to the GCS score, SBP, and RR and summed to create an RTS value from 0 (most severe physiologic disturbance) to 7.8408 (normal or near-normal physiology).[23] The RTS was calculated for each patient.

Statistical Analysis

The in-hospital mortality of injured adults aged ≥18 years transported by HEMS was compared with the in-hospital mortality of injured adults aged ≥18 years transported by ground ambulance. The demographic, clinical, transport type, and mortality variables were categorical variables. Age, ISS, and RTS were analyzed as continuous variables. The data were not weighted. In-hospital mortality was calculated for different demographic and injury severity groups using descriptive statistics (percentages, 95% confidence intervals [CIs]). To assess the association of mortality with mode of EMS transport after controlling for potential confounders (age, gender, ISS, RTS), a standard logistic regression model without stepwise procedures was used. The results of the logistic regression are presented as adjusted odds ratios (AOR) with 95% CIs and p-values. In order to detect multicollinearity among all of the dependent variables, a variance inflation factor test was used. This test is preferred when looking at dependent variables that are not normally distributed, such as ISS values. The variance inflation factor for the model was well below the 2.5 variance inflation factor threshold for logistic regression models ($vif = 1.25$).[24] Mortality is higher in trauma patients aged ≥55 years,[21,25] so subanalyses of those aged 18–54 years and those aged ≥55 years were performed to assess outcome differences. SAS statistical software version 9.2 was used for the data analysis (SAS Institute, Inc., Cary, NC).

RESULTS

The in-hospital mortality for all participants (n = 56,744) was 4.5%. Of these, 46,695 (82%) patients were transported to trauma centers by ground ambulance and 10,049 (18%) were transported by HEMS (Table 1). There were 2,556 in-hospital deaths; 1,874 patients (4.0% of total) were transported by ground and 682 (6.8% of total) were transported by HEMS. Controlling for age, gender, and injury severity, the odds of mortality were 39% lower in those transported by HEMS compared with those transported by ground (AOR = 0.61, 95% CI = 0.54–0.69) ($p < 0.0001$) (Table 2).

Age and Gender

Male patients accounted for 39,227 (69%) of all transports and, of those, 1,885 (4.8%) died. Female patients accounted for 17,517 (31%) transports and, of those, 671 (3.8%) died. The majority of both helicopter transports (76%) and ground transports (69%) involved male patients. Male patients had a higher odds of death (AOR = 1.23, 95% CI = 1.10–1.38) ($p = 0.0004$) compared with female patients (Table 2).

There were 42,316 (75%) transports among the patients aged 18–54 years and, of those, 1,559 (3.7%) died. In contrast, of the 14,428 (25%) transported patients aged ≥55 years, 997 patients (6.9%) died. A higher percentage of those aged 18–54 years (19%) than those aged ≥55 years (14%) were transported by HEMS (Table 1). The odds of death increased significantly with each year of advancing age (AOR = 1.040, 95% CI = 1.037–1.043) (Table 2).

A subanalysis of adults aged 18–54 years demonstrated a 49% decrease in the odds of mortality for those transported by HEMS compared with ground ambulance (AOR = 0.51, 95% CI = 0.44–0.60) ($p < 0.0001$). There was no difference between male and female patients (AOR = 1.17, 95% CI = 1.00–1.37). The odds of mortality increased with each year of advancing age within this age group (AOR = 1.016, 95% CI = 1.010–1.022). An increase in injury severity decreased odds of survival; mortality increased with each unit of ISS (AOR = 1.073, 95% CI = 1.068–1.078) and decreased with each unit of RTS (AOR = 0.46, 95% CI = 0.44–0.47) (Table 2).

A subanalysis of adults aged ≥55 years showed no difference in the odds of death in those transported by HEMS compared with those transported by ground ambulance (AOR = 0.92, 95% CI = 0.74–1.13) ($p = 0.4173$). In this age group, male patients had a significantly higher odds of death (AOR = 1.42, 95% CI = 1.20–1.68) compared with female patients. The odds of mortality increased 7% with each year of age (AOR = 1.07, 95% CI = 1.06–1.08). An increase in injury severity decreased odds of survival; mortality increased 9% with each unit of ISS (AOR = 1.10, 95% CI = 1.09–1.11) and decreased with each unit of RTS (AOR = 0.49, 95% CI = 0.46–0.52) (Table 2).

Injury Severity

Applying the anatomic injury score ISS, there were 14,761 (26%) severely injured patients (defined as ISS ≥15), and 2,118 (14%) of them died. In contrast, the mortality rate for non–severely injured patients (ISS <15) was 1%. Severely injured patients were transported by HEMS with greater frequency than those who were not severely injured (30% vs. 14%) (Table 1). The odds of death significantly increased with each unit of ISS (AOR = 1.080, 95% CI = 1.075–1.084) (Table 2).

Applying the RTS physiologic injury score, there were 4,605 (8%) patients with RTS <6 and there was a 35% in-hospital mortality rate ($n = 1{,}597$). In contrast, the mortality rate for those with RTS ≥6 was 2% ($n = 959$). The rate of HEMS transport for those patients with RTS <6 was 35% ($n = 1{,}598$) and for those with RTS ≥6 it was 16% ($n = 8{,}451$). The odds of death greatly decreased with each unit of RTS (AOR = 0.46, 95% CI = 0.45–0.48).

DISCUSSION

Helicopter EMS plays an important role in transporting injured patients to definitive care. A primary benefit of HEMS has been thought to be shorter time periods to treatment.[10] Although the concept of the "golden hour" may not be supported by the evidence,[26] longer time intervals between severe injury and definitive care have been associated with a significant increase in mortality.[27] It has been estimated that 84% of all U.S. residents have access to a level I or II trauma center within one hour and about one-third of these residents have this access only if flown by helicopter.[28]

There are four additional benefits of HEMS that may not be as readily apparent as shorter transport times. First, air medical crews can provide a higher level of care than may be available by ground ambulance in terms of both equipment and medical expertise.[10,11] Second, the environment of the injury scene can sometimes be accessed only by helicopter.[11] Third, because of the inherent speed of the helicopter compared with ground ambulance, HEMS can cover longer distances in a shorter time period, and has been effectively utilized in transport from remote areas.[29] Fourth, HEMS is sometimes used in areas of sparse ground EMS availability in which a ground transport to the trauma center may leave a community without EMS coverage for an extended period of time.[11]

Studies have shown improved outcomes with HEMS transport,[30–34] finding as much as a 52% reduction in mortality[8] and saving as much as one to 12 lives per 100 uses of HEMS.[35] Many studies have shown no such improvement.[26,36–40] Given the relative lack of clear evidence for the benefit in terms of outcome, and in view of the high costs and the issue of safety, HEMS systems are under increasing scrutiny.[9,12] This is one of the few large studies to evaluate the association between EMS transportation mode and mortality. Approximately 58,000 records of patient transports from over 60 trauma centers across the United States were used in the analysis.

The finding of a 39% decrease in the odds of mortality in adults transported by HEMS compared with ground ambulance is noteworthy. This figure is greater than the 20–30% reduction in mortality seen in most of the previous studies. A large study using the NTDB Research Data Set (RDS) found a lower but significant mortality reduction of 22%.[30] The difference in the design of the two studies may account for this large difference. Our study used the NTDB NSP data set, which

TABLE 1. In-Hospital Mortality in Injured Adults Aged ≥18 Years Transported by Ground or Helicopter Air Ambulance, by Selected Demographic and Injury Severity Characteristics—National Trauma Data Bank National Sample Program, 2007

		Mode of Ambulance Transport		
Characteristic	Deaths* n (%)	Ground n (%)	Air† n (%)	Total n
Gender				
All	2, 556 (4.5%)	46, 695 (82.3%)	10, 049 (17.7%)	56,744
Male	1, 885 (4.8%)	32, 058 (81.7%)	7, 606 (18.3%)	39,227
Female	671 (3.8%)	14, 637 (83.6%)	2, 999 (16.4%)	17,517
Age				
18–54 years	1, 559 (3.7%)	34, 263 (81.0%)	8, 053 (19.0%)	42,316
55+ years	997 (6.9%)	12, 432 (86.2%)	1, 996 (13.8%)	14,428
ISS				
15+	2, 118 (14.3%)	10, 397 (70.4%)	4, 364 (29.6%)	14,761
<15	438 (1.0%)	36, 298 (86.5%)	5, 685 (13.5%)	41,983
RTS‡				
<6	1, 597 (34.7%)	3, 007 (65.3%)	1, 598 (34.7%)	4,605
6+	959 (1.8%)	43, 688 (83.8%)	8, 451 (16.2%)	52,139
Transport mode				
Ground	1, 874 (4.0%)	46, 695 (100.0%)	0 (0.0%)	46,695
Air†	682 (6.8%)	0 (0.0%)	10, 049 (100.0%)	10,049

*Patients who were admitted to the emergency department and died prior to hospital discharge.
†Rotary wing (helicopter) transport only.
‡Odds of mortality per each RTS unit.
ISS = Injury Severity Score; RTS = Revised Trauma Score.

is a national probability sample of up to 100 level I and II trauma centers, in order to make a more accurate inference to the population of patients seen in U.S. trauma centers.[41] The NTDB RDS is a nonweighted aggregation of all records sent to the NTDB, to include those from level III, IV, and V and undesignated trauma centers, which rarely accept HEMS patients. We included only hospitals that accepted both HEMS and ground transports in order to more effectively isolate the impact of mode of transportation. In addition, we controlled for physiologic injury by using the RTS to obtain a weighted injury score, and treated it as a continuous variable.

Patient age is an important factor in the association of mortality and the mode of ambulance transport. A subanalysis using data from adults aged 18–54 years showed a 49% decrease in the odds of mortality associated with HEMS transport compared with ground ambulance, which is consistent with a previous report.[30] In contrast, there was no significant difference in the odds of death for those aged ≥55 years, suggesting that transport mode may not provide a similar positive effect on mortality in injured older adults. It may be that the benefits of HEMS transport on mortality are not realized in older adults because of diminished physiologic reserve, more comorbid conditions, and certain medications[42] that complicate or resist successful resuscitation or treatment, regardless of transport time or availability of a higher level of care. In addition, older adults have higher in-hospital mortality rates from complications that are unrelated to the original injury.[43] The results of this analysis should be an important part of the national debate regarding utilization of these services and the selection criteria for

TABLE 2. Adjusted Odds Ratios of In-Hospital Mortality in Injured Adults Aged ≥18 Years Transported by Ground or Air Ambulance, Controlling for Gender, Age, Injury Severity Score, and Revised Trauma Score—National Trauma Data Bank National Sample Program, 2007

	Adults ≥18 Years			Adults 18–54 Years			Adults ≥55 Years		
Characteristic	AOR	95% CI	p-Value	AOR	95% CI	p-Value	AOR	95% CI	p-Value
Gender									
Male	1.231	1.097–1.380	0.0004	1.166	0.995–1.370	0.0592	1.420	1.200–1.683	<0.0001
Female	*Reference*	*Reference*		*Reference*	*Reference*		*Reference*	*Reference*	
Age*	1.040	1.037–1.043	<0.0001	1.016	1.010–1.022	<0.0001	1.071	1.062–1.081	<0.0001
ISS†	1.080	1.075–1.084	<0.0001	1.073	1.068–1.078	<0.0001	1.098	1.090–1.107	<0.0001
RTS‡	0.464	0.45–0.477	<0.0001	0.457	0.442–0.471	<0.0001	0.488	0.463–0.515	<0.0001
Transport mode									
Air§	0.607	0.535–0.688	<0.0001	0.513	0.439–0.599	<0.0001	0.916	0.740–1.133	0.4173
Ground	*Reference*	*Reference*		*Reference*	*Reference*		*Reference*	*Reference*	

*Odds of mortality per each year of age.
†Odds of mortality per each ISS unit.
‡Odds of mortality per each RTS unit.
§Rotary wing (helicopter) transport only.
AOR = adjusted odds ratio; CI = confidence interval; ISS = Injury Severity Score; RTS = Revised Trauma Score.

patients who would obtain the greatest benefit from HEMS transport among trauma patients.

Although HEMS has been beneficial to trauma care, there have been concerns about excessive utilization, costs, and safety. Enhanced availability of HEMS has resulted in its use when the severity of injuries sustained may not have warranted it.[44–46] As competition in the health care industry has heightened, there have been increasing concerns about the costs and necessity of HEMS.[47] Even after the large initial investment for a HEMS aircraft, non–inflation-adjusted estimated annual operating costs from 1997 exceeded $2 million.[13]

In addition to financial concerns, there has been increasing focus on the number of HEMS crashes and resulting deaths of health care personnel and transported patients.[12,48] Between 1972 and 2008, there were 264 HEMS crashes in the United States, with 264 fatalities in 98 of these crashes. The number of crashes has been increasing. In 2008, there were 13 crashes resulting in 29 deaths, the highest number of fatalities in a single year to date.[9] Despite the increase in fatalities, due to the greater utilization of HEMS, it has been estimated that the actual fatal crash rate has decreased from 10 per 100,000 flight hours in 1980 to two per 100,000 hours in 2008.[9] In evaluating risk associated with HEMS transport, it should be recognized that ground ambulance transport is also not without risk; 300 fatal crashes accounted for 357 fatalities during 1991–2002.[49]

In an effort to develop evidence-based guidelines for field triage to trauma centers, the National Center for Injury Prevention and Control (NCIPC) at the Centers for Disease Control and Prevention (CDC) convened the National Expert Panel on Field Triage in 2006. This effort resulted in the 2006 Field Triage Decision Scheme.[50] Although the Decision Scheme identifies those patients who would most benefit from care in a trauma center, it does not address the mode of transportation.

There is a lack of scientific data that identifies those patients who would benefit from HEMS. Consequently, there is no consensus in guidelines for HEMS utilization. Limited national guidelines include those published by the National Association of EMS Physicians (NAEMSP) in 2003[11] and a brief policy statement from the American College of Emergency Physicians (ACEP) issued in 1999, with a revision in 2008.[51] Some private HEMS operators[52] and government EMS agencies[53,54] have posted their own guidelines for helicopter use. However, if flight conditions permit, most HEMS operators will fly when they have been requested, as required by law in many states.[55]

Limitations and Future Research

This study was subject to several limitations. The trauma centers included in this study were not nationally representative and the findings may not be applicable to non–trauma centers. Distance to the trauma center from the injury scene location is a key factor in transport decisions and a possible confounder. In rural and remote areas, patients are more likely to be considered for HEMS transport and those in urban areas are more often considered for ground EMS. Interfacility transports were excluded to better isolate the impact of HEMS on the acutely injured patient from injury scene to initial treatment; as a result, the bulk of HEMS trauma utilization in some regions was not studied. Also, we were not able to control for resource prevalence; HEMS may be more likely to be used if more helicopters are available. An important variable to control in future research is mechanism of injury (blunt vs. penetrating trauma)[56]; however, these data were not available within this data set. Mortality was the only outcome studied; other outcomes (e.g., disability, intensive care unit days, hospital length of stay) would be important to assess in future studies.

Conclusion

The benefits as well as the costs and risks of HEMS transport of injured patients are important considerations for medical providers, public health practitioners, private and public insurers, and policy makers. In this large study, the use of HEMS for the transport of trauma patients is associated with reduced mortality in adult patients under age 55 years. In this study, HEMS did not improve mortality in adults aged $\geq$55 years. An established method of selecting those patients who will benefit the most from helicopter transport is expected to enhance this reduction in mortality. To further characterize differences, a study comparing other outcome measures (e.g., transient and permanent disability) for those transported by helicopter and ground ambulance is warranted. Additionally, a more comprehensive examination of the detailed costs and inherent risks of crashes associated with HEMS and the reduced mortality associated with helicopter transports is necessary to fully determine the degree to which HEMS is beneficial to society.

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