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Helicopter Emergency Medical Services for Trauma: An Update

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Abstract
Purpose of Review Helicopter emergency medical services (HEMS) have become a well-established component of most contemporary trauma systems throughout the world. HEMS is associated with significant costs, safety concerns, and potential inappropriate use. In this update, we briefly review the historical context, evidence for clinical effectiveness, and methods for ensuring proper utilization of HEMS.
Recent Findings A recently validated prehospital triage score—the Air Medical Prehospital Triage (AMPT)—is reviewed. Examples of system improvements using evidence-based practices and adherence to both national and local utilization guidelines are also discussed.
Summary Appropriate triage for HEMS use remains an important goal for developed trauma systems. Although associated with significant costs and safety concerns, recent literature has highlighted the association of HEMS with improved outcomes for trauma patients.

Keywords Helicopter emergency medical services · Trauma · Air ambulance · Aeromedical critical care · Emergency medical services · Air medical transport

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Introduction

Unintentional injury is the third leading cause of death in the United States and first leading cause of death in ages 1–44 worldwide [1–3]. With approximately 214,000 people dying annually in the US, this translates to 1 death every 3 min [1]. Beyond the lasting physical, emotional, and psychosocial toll, trauma results in a significant economic burden, estimated in 2013 to be cost over $671 billion USD [1]. To help address such a momentous threat to public health, the use of helicopter emergency medical services (HEMS) for the transportation and treatment of injured patients has become commonplace in most developed nations. Current research, including well-designed observational studies that control for multiple known confounders, has helped clarify which traumatically injured patients derive the greatest benefit from HEMS. This article provides an update regarding the clinical effectiveness associated with HEMS with a focus on appropriate utilization and challenges associated with this limited and resource-intensive modality.

Historical Context

Increased utilization of HEMS began in the 1950s during the Korean war when over 20,000 evacuations were performed using the Bell Model 47 helicopter [4]. Prehospital transport time was reduced significantly with the use of the helicopter, decreasing from approximately 5 h in Korea to 1 h in Vietnam [5, 6]. Coupled with early treatment capabilities, the helicopter has historically been considered a key factor in helping reduce combat mortality despite worsening injury severity by facilitating early access to surgical care [6–8]. Military advances, which included the use of HEMS, led to greater civilian use within emergency medical services (EMS) systems, and the "golden hour" concept was formulated in the 1970s by R Adams Cowley [9, 10]. As an emphasis was shifted to early intervention with a temporal association with better outcomes, the proliferation of rapid transportation via rotor wing aircraft emerged.

Clinical Effectiveness

The benefits of Helicopter Emergency Medical Services (HEMS) compared to Ground Emergency Medical Services (GEMS) are still considered controversial by some despite the publication of several large observational studies using advanced statistical techniques to control for known confounders [11–15]. As the distance from a trauma center increases, the speed at which HEMS can transport a patient, in comparison to GEMS, becomes more marked. In a 2012 retrospective US study examining 223,475 patients from the National Trauma Data Bank (NTDB) with blunt or penetrating trauma and an Injury Severity Score (ISS) of 15 or more, transport by HEMS compared to ground EMS was independently associated with improved survival to hospital discharge after controlling for multiple cofounders in a propensity score-based multivariable logistic regression analysis [16]. This study, the largest observational HEMS study to date, demonstrated a 15%-survival advantage and a number needed to treat (NNT) of 65 to save one life [4, 16].

The question regarding which elements of HEMS are most beneficial has not been fully answered, but several recent studies have highlighted factors thought to be contributory to improved patient outcomes [17]. Speed may not be the sole factor in mortality benefit of HEMS; crew composition and expertise are likely equally important since most HEMS systems are staffed by highly experienced physicians, nurses, paramedics, and other healthcare professionals. In a 2013 retrospective study of 13,000 trauma patients in Germany, HEMS patients, despite having a significantly higher incidence of multiple organ dysfunction and sepsis, demonstrated a survival benefit compared to GEMS patients [18]. Patients in the HEMS group were more likely to be intubated, undergo thoracostomy tube placement, and receive sedation or vasopressors. Subgroup analyses indicated a survival benefit independent of Level I trauma center admission status, possibly owing to improved outcomes linked to clinical capabilities. Other recent studies have demonstrated high success rates with advanced airway interventions and prevention of hypoxia and hypotension by HEMS crews [19, 20]. In another large study with over 8000 patients, patients with low Glasgow Coma Scale scores (< 8), abnormal respiratory rates, or chest trauma benefited significantly from HEMS, even when GEMS transport was faster [21].

It is likely that some combination of speed of transport, crew composition and proficiency, and trauma center access contribute to HEMS outcomes [22–25]. HEMS is an integral part of large, well-organized trauma systems, and it is important to consider that access to these high volume, superbly staffed facilities may confer benefits to the patient beyond immediate high-level trauma and critical care needs, such as access to multidisciplinary care teams and specialists, and resources to support aggressive early rehabilitation. From an epidemiological perspective, HEMS may be considered a mediator in a causal pathway leading to improved outcomes for patient with severe trauma. HEMS may *mediate* improved outcomes by decreasing prehospital time and therefore ensuring equivalent outcomes compared to GEMS patients injured in closer proximity to a trauma center (Fig. 1).

To define additional beneficial effects of HEMS, studies examining endpoints related to health-related quality of life, beyond traditional outcomes of survival and morbidity, are needed [26].

In 2013 and 2015, Cochrane systematic reviews were conducted to determine if HEMS is associated with improved morbidity and mortality compared with GEMS [25, 27]. The primary outcome of interest was survival to hospital discharge; secondary outcomes included quality-adjusted life years (QALYs) and disability-adjusted life years (DALYs). In the 2015 review, HEMS and GEMS groups were compared using adult population data only (> 16 years of age) and patients with an injury severity score (ISS) > 15. Mortality data from 282,258 patients in 28 studies were analyzed; no studies were found to properly address the secondary outcomes (QALYs and DALYs). Due to the methodological weaknesses of the available literature, and the considerable heterogeneity of effects and study methodologies, an accurate composite estimate of the benefit of HEMS could not be determined [27]. Nonetheless, of the studies that used advanced regression techniques to statistically control for known confounders, the majority demonstrated a statistically significant effect estimate in favor of HEMS over GEMS. The results from these studies, as well as other studies published after the Cochrane review, are listed in Table 1.

Four additional studies were included in a subgroup analysis examining *transfer* of patients to trauma centers by GEMS or HEMS from lower-level centers, with a positive survival benefit attributed to patients transferred by HEMS [27]. Nevertheless, more recent work has shown that HEMS is often associated with overtriage for patients requiring interfacility transfer [28], and the use of HEMS for this purpose remains inadequately studied.

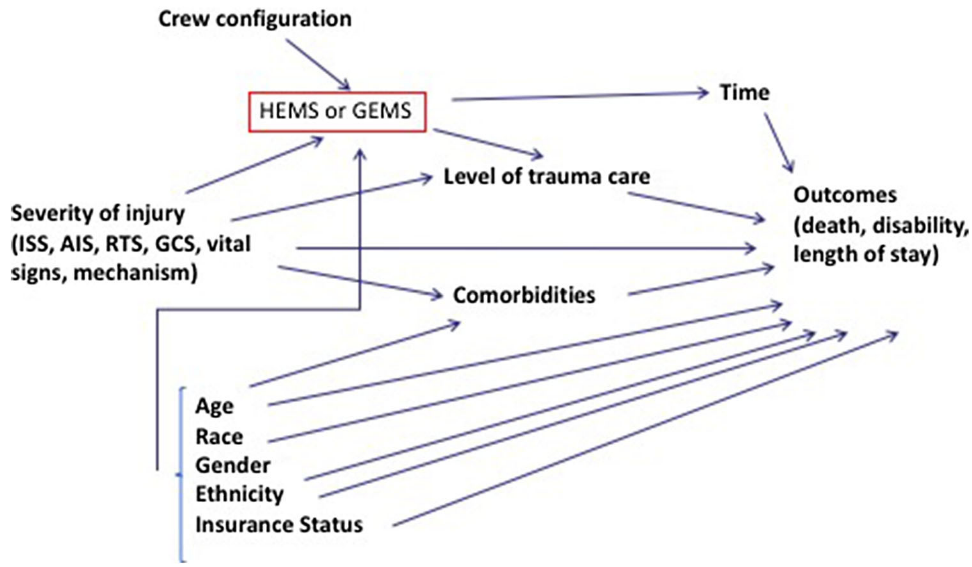

Fig. 1 Directed acyclic graph (DAG) depicting HEMS as a mediator for improved outcomes in trauma patients

Safety and Cost

There is a significant financial cost associated with HEMS, with estimates ranging from $115,000 USD to $4.5 million USD per institution in 2010 [29]; each transport may cost between $12,000 USD and over $25,000 USD. The hazards posed to rotor ring aircraft responding to the scene of a trauma are unique as there are a plethora of variables beyond the normal challenges of visibility, wind, and terrain. The landing zone is often chaotic, unsecure, and abounding with hazards not typically found at helipads (e.g., traffic, pedestrians, animals, wires, debris subject to backwash). The safety concerns associated with HEMS are substantial; fatalities after HEMS crashes are closely related to post-crash fires and nighttime operations [30]. To address these concerns, in February 2014, the Federal Aviation Administration (FAA) released Final Rule 2010-0982 mandating HEMS agencies to adopt enhanced procedures for flying in difficult weather, at night, and in remote terrain and required minimum standards for

Table 1 Studies that have used multivariate logistic regression to adjust for potential confounders

Study	Number of patients	Odds ratio for survival	95% confidence interval
Andruskow [18]	HEMS: 4989	1.33	1.16–1.57
	GEMS: 8231		
Brown [43]	HEMS: 41,987	1.22	1.18–1.27
	GEMS: 216,400		
Bulger [44]	HEMS: 703	1.11	0.82–1.74
	GEMS: 1346		
Desmettre [45]	HEMS: 516	1.47	1.02–2.13
	GEMS: 1442		
Galvagno [16]	HEMS: 47,637 (7)	1.16	1.14–1.17
	GEMS: 111,874 (7)		
	HEMS: 14,272 (8)	1.15	1.13–1.17
	GEMS: 111,874 (8)		
Koury [46]	HEMS: 168	1.6	0.77–3.34
	GEMS: 104		
Ryb [47]	HEMS: 29.472	1.78	1.65–1.92
	GEMS: 162,950		
Zhu [48]	HEMS: 469	2.69	1.21–5.97
	GEMS: 580		

equipment including radio altimeters and terrain avoidance warning systems [31]. Based on the considerable financial and safety considerations related to HEMS, indications for proper use are paramount. Appropriate HEMS triage is truly a daunting task made complex by a multitude of variables and their interactions.

Triage Considerations: The Air Medical Prehospital Triage (AMPT) Score

Determining which trauma patients would benefit from HEMS transport is challenging due to limited or conflicting information in the field, and investigators have attempted to study methods for ensuring proper patient selection for maximum clinical benefit. In 2012, Brown et al. attempted to identify which patients would most benefit from HEMS transport and limit overtriage, as prior to this, there was no uniformed scoring system and varying extrapolations of standard trauma triage were used [32]. They retrospectively examined 258,387 subjects that were transported by either GEMS or HEMS using the preexisting National Trauma Triage Protocol (NTTP), developed jointly by The American College of Surgeons Committee on Trauma and the Centers for Disease Control in 2009. The NTTP is based on the stepwise identification of four aspects of clinical presentation that should be readily identifiable to emergency medical service providers at the scene of injury, to determine if the patient should be transported to a trauma center [33]. These include physiologic criteria, anatomic criteria, mechanism of injury criteria, and special considerations criteria that are evaluated in a sequential fashion to identify patients who should be transported to a trauma center. In this study, HEMS patients were more severely injured compared to GEMS patients, and HEMS was as an independent predictor of survival in a subset of subjects with certain triage criteria, including penetrating injury, GCS < 14, RR < 10 or > 29 breaths per minute, and age > 55 years [32]. The authors aptly recognized that adopting a scoring system intended to evaluate the need for transport to a trauma center cannot be equally used in identifying which patients would benefit from air versus ground transport, although a subset might benefit. Recent work has also confirmed that physiological criteria do not predict anatomical severity of injury, and determination of ISS—which has been correlated with a HEMS benefit when the ISS is greater than 15 [16]—is problematic in the field [34].

In 2016, the same group from Pittsburgh worked to develop and internally validate a simple triage score that could prospectively identify trauma patients at the scene of injury who would potentially benefit from HEMS transport compared to GEMS transport [35]. Using the National Trauma Databank (NTDB; 2007–2012), criteria associated with a survival benefit when HEMS was used were defined, and an Air Medical Prehospital Triage (AMPT) instrument was established. The AMPT incorporates seven simple criteria, adapted from previous existing triage guidelines, to generate a point total for an individual patient and provides a triage recommendation for HEMS if ≥ 2 points or GEMS transport if < 2 points based on patient-level factors [35, 36].

Age > 55 was an eighth triage criteria that was associated with improved survival; however, this variable was omitted as including it would have increased triage rates in the validation group by 50%, which was significantly more than were actually transported [35]. Transport modes of patients with scores of 0 or 1 did not impact survival, whereas ≥ 2 conferred an adjusted odds ratio of survival of 1.28 (CI 1.21–1.36, $p < 0.01$). The benefit of the AMPT Score is that it reflects existing triage criteria and is usable in the field by only minimally trained first responders. Nevertheless, there are several potential limitations with the AMPT. The score was developed using a retrospective study design and NTDB data. NTDB data are not population based, are skewed towards large trauma centers, and do not always specify the mechanism of injury [35].

To address concerns about the validity of the AMPT, the score was externally validated with a retrospective study using a different trauma registry [36]. The 2000–2013 Pennsylvania Trauma Outcomes Study (PTOS) registry was used to identify patients with a survival benefit from HEMS compared to GEMS. The PTOS offered the advantage of a different data set, case mix, and time period, as well as access to an overall more granular data set [36]. Patients were excluded if they were transferred from another hospital or burn was the primary mechanism of injury. Patients with AMPT Scores ≥ 2 points were triaged to HEMS and those with < 2 points to GEMS. Data were adjusted for demographics, mechanism, vital signs, interventions, and injury severity. A multilevel Poisson regression model was created and applied. Subgroup analyses were performed for patients treated by advanced life support providers and patients with transport times longer than 10 min which reflected the 25th percentile of transport times. For patients triaged to GEMS by the AMPT score, actual transport mode was not associated with survival (adjusted relative risk, 1.004; 95% confidence interval, 0.999–1.009; $p = 0.08$). For patients triaged to HEMS by the AMPT score, actual HEMS transport was associated with a 6.7% increase in the relative probability of survival (adjusted relative risk, 1.067; 95% confidence interval, 1.040–1.083, $p < 0.001$). Similar results were seen in all subgroups [36]. In summary, the AMPT is currently the most rigorously studied prehospital triage tool for determining which adult trauma patients might benefit from HEMS.

Triage Considerations: The Tyranny of Distance

EMS transport of trauma patients is affected by a breadth of environmental variables such as weather and seasonality, time of the week and day, population density, traffic patterns, and many other factors [37]. Geospatial techniques have been developed to inform future applications of HEMS utilization. In an effort to characterize the impact of traffic, weather, and geography, data from PTOS were examined by Chen et al. to determine a possible threshold whereby HEMS transport is faster than GEMS [21]. Distance between a zip code centroid (i.e., geometric center of a zip code where an injury occurred) and trauma center was calculated using straight-line distance for HEMS, and driving distance from geographic information system's network analysis was used for GEMS. Weather data were obtained from the National Oceanic and Atmospheric Administration (NOAA) Climate Data online tool for the weather station closest to the receiving trauma center and dichotomized as either adverse or clear weather. Overall, HEMS transport was shown to be faster than GEMS when distance to a trauma center was 7.7 miles or greater in Pennsylvania. Transport during peak traffic periods reduced this threshold by 1.4 miles, and adverse weather increased this threshold distance by 9.8 miles. When accounting for both traffic and weather, similar effects were seen in reducing the threshold distance during peak traffic and increasing the threshold distance during adverse weather. This study is one of the largest HEMS studies to adopt geospatial techniques to help guide transport decisions. In the future, geospatial techniques are likely to be employed to curtail healthcare expenditures with a minimal impact on patient outcome.

Future Directions

Despite the inability to conclusively and unanimously identify the correct patient for HEMS transport, vigilance in appropriate employment of this HEMS can have a significant impact on cost savings, safety, and patient outcomes. In response to increased utilization and in an effort to improve system efficiency, the state of Maryland implemented changes in field triage protocols. From 2001 to 2011, the number of HEMS transports for trauma patients was reduced by 55%, yet mortality did not increase despite a statistically significant increase in ISS [38].

Protocols that mandated physician consultations for HEMS transport or required ground transport based on distance from a trauma center were associated with a decreased number of flights. These results were accomplished using statewide criteria that closely resembled national triage guidance from the American College of Surgeons and Centers for Disease Control [33]. Using the AMPT score, a nationally representative cohort was analyzed using Markov modeling [39]. Current HEMS triage practices were shown to have an incremental cost-effectiveness ratio (ICER) of $255,333 USD per quality-adjusted life-year compared with using the Air Medical Prehospital Triage score, which is significantly more than the generally accepted threshold of $100,000 USD per quality-adjusted life-year for cost-effective medical interventions [39].

Conclusion

HEMS has become a well-established component of contemporary trauma systems. HEMS provides advanced level care to trauma patients with benefits being derived from the ability to cover long distances rapidly, the care of providers with advanced skills and who typically have been exposed to large volumes of trauma, and the integration into advanced trauma networks and systems. Prospective studies are needed to better examine and validate triage scoring systems for HEMS, with the goal of establishing a national standardized system and set of guidelines [40]. As guidelines are established and practices more standardized, subgroup analyses of special patient populations are warranted; some of these analyses have recently been conducted [41, 42] and many more are ongoing. Use of HEMS for interfacility transport requires further study. As with other advances in trauma and critical care medicine, the nature of military conflicts may continue to drive innovation and application. With battlefield geography becoming more disconnected, force composition trending towards smaller, more mobile units, and the need (and access) to forward surgical theaters more unpredictable, use of HEMS will continue to evolve. Advances in our understanding of the pathology of trauma, damage control resuscitation, coagulopathy, and early identification and prediction of injury severity, will allow for the refinements in the use of HEMS.

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Compliance with Ethics Guidelines

Conflict of interest Benjamin Fedeles declares no potential conflicts of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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