HELICOPTER EMS

UTILIZATION AND OUTCOMES: AN EVIDENCE-BASED OVERVIEW

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Introduction

Discussion aim

This discussion strives to overview evidence addressing benefits accrued by utilization of helicopter EMS (HEMS). The primary goal is to analyze the HEMS literature to describe, qualitatively and quantitatively, potential benefits of air medical transport. Secondary goals include evaluating HEMS study methodologies and addressing HEMS triage and cost-effectiveness.

Monograph organization

The monograph is divided into sections. After outlining the discussion objectives, the paper continues with background information provided to facilitate interpretation of HEMS studies. Next comes an overview of the HEMS outcomes literature, with annotations for a selection of publications. The evidence's lessons are summarized in a section examining air transport benefits to patients and regions. The monograph concludes by addressing the related issues of cost-effectiveness, triage, and utilization review.

The state of the evidence

Previous HEMS reviews include objective analyses such as one conducted by the independent Institute of Health Economics, prepared for the Canadian health ministry in Alberta. That report’s authors, after reviewing all available studies from the year 2000 to 2007, concluded: “Overall, patients transported by helicopter showed a benefit in terms of survival, time interval to reach the healthcare facility, time interval to definitive treatment, better results, or a benefit in general.”1 Unfortunately, the quality of the overall literature has been found to be low, and also too heterogeneous to allow meta-analysis.2

Although flawed, the evidence does exhibit some consistency, particularly with respect to findings of the methodologically rigorous studies in the arena (trauma) characterized by the most evidence. Authors of recent meticulous HEMS analysis point out that, within studies meeting methodological criteria for high quality, there is noteworthy similarity of point estimates – odds ratios (ORs) of 1.2 to 1.5 – for HEMS-associated trauma survival improvement.3

HEMS use for trauma has historically been based on reducing the time interval between injury and medical care provided by either HEMS crews or trauma center personnel. With the elucidation of direct links between time savings and outcome in non-trauma cases, HEMS’ logistics advantages have led to close examination of helicopter deployment for patients other those with injuries.

The mantras “Time is brain” and “Time is heart” will in some cases inevitably translate into benefit from air transport as compared to ground EMS (GEMS) transport if the latter is associated with longer time frames. If the helicopter gets a patient to time-windowed, outcome-improving therapy that would have been missed if GEMS were used, then there is utility to HEMS in that case. There is similar utility if HEMS gets a patient to time-critical therapy in a clinically significant quicker time frame than would have been achievable with GEMS. Ties from time savings to survival benefit have been suggested by studies of HEMS utility for lysis-eligible patients with ischemic cerebrovascular accident (iCVA)4,5 and also in patients with ST-elevation myocardial infarction (STEMI) who undergo transport for percutaneous coronary intervention (PCI).6,7

It would be a mistake to assume that HEMS always saves time to definitive care.8,9 However, the proven utility of HEMS in some time-critical situations has been acknowledged in joint position statements from organizations such as the American College of Emergency Physicians (ACEP) and the National Association of EMS Physicians (NAEMSP).10

Justifying attention to HEMS

As is so often the case in evidence-based medicine (EBM), the proper question regarding HEMS is not “Is it ever helpful?” but rather “When is it helpful?” Some investigators 11 have argued that regional costs of HEMS are no higher than costs of response-time-equivalent GEMS critical care coverage. But it is understandable that HEMS’ nature of
concentrating resources on a few high-cost vehicles will translate into continued perception (even among some HEMS advocates) of air medical transport as being a “high-cost” option.

The need for HEMS discussion is based in part on continuing uncertainty about air transport’s role, and in part on the fact that HEMS is already a significant and growing part of EMS. A look at the time period of roughly a decade tells the story: a 2007 overview estimated that in the USA, 753 helicopters and 150 dedicated fixed-wing (FW) aircraft were in EMS service, providing about 3% of all ambulance transports. Less than a decade later, 2015 data (accessed in late 2016) from the Atlas & Database of Air Medical Services (www.ADAMSairmed.org) tabulated 1045 EMS helicopters and 362 FW aircraft providing transport. Since HEMS is clearly on the scene, and is growing in presence, there is impetus to closely examine its optimal utilization.

Different portions of this monograph will have different relevance to various readers. Healthcare and EMS regional systems are widely disparate, and none of this paper’s information should be applied without consideration of regional variability. Between HEMS programs, mission profiles can be markedly different. A typical USA HEMS program reports performing 54% interfacility transports, 33% scene runs, and 13% mission types that fall into “other” categories (e.g. neonatal, pediatric, transplant-related) but the mission profile may be vastly different for a HEMS program elsewhere. The message to keep in mind is: make sure the HEMS evidence presented here (or elsewhere) is interpreted in light of regional needs.

Since few would argue that HEMS benefit is always predicated solely on time and logistics, any consideration of HEMS outcomes touches upon the broader subject of advanced levels of care in the prehospital setting. (N.B. For purposes of consistency within this monograph, “prehospital” is interchangeable with “out-of-hospital” and encompasses both scene and interfacility transports.) The HEMS crews’ extended practice scope offers circumstances well-suited for assessing high-level advanced life support (ALS) care and its potential benefits. The best example of this lies in airway management and endotracheal intubation (ETI). Studies assessing prehospital ETI have provided important – if unintended – insight into HEMS’ salutary impact on outcome. Those reviewing the potential benefits of HEMS have often stressed the importance of considering crew capabilities as a separate issue from vehicle-related issues; where such separation is possible, it is reasonable to try and consider clinical care and logistics as two distinct pathways to improved outcome.

Many questions remain unanswered about HEMS. However, there is a large body of evidence addressing HEMS’ potential outcomes impacts, that is usually paid insufficient attention during HEMS debates. The literature may or may not provide concrete answers to given questions about HEMS, but there is likely guiding literature of some sort on most questions; it is a goal of this presentation to facilitate the EBM process as pertains to HEMS, by overviewing the existing knowledge base.

Discussion objectives

The discussion objectives are outlined below. These objectives can be used (for CME documentation purposes) as the objectives for Grand Rounds presentations covering this material. The material for the monograph is divided into the following sections:

1) Provide background on prehospital outcomes assessment studies and methodology.
2) Introduce the literature assessing HEMS outcomes.
3) Discuss possible benefits of HEMS to patients and healthcare systems.
4) Overview HEMS cost-benefit and cost-effectiveness considerations.
5) Address HEMS triage and utilization challenges.
6) Outline HEMS use recommendations.
7) Summarize evidence basis for judicious HEMS use.
8) Assemble listing of most important studies pertinent to HEMS outcomes considerations.
Section 1: Defining endpoints

HEMS can potentially have influence – positive or negative – on myriad outcomes relating to individual patients, prehospital systems, and regionalized healthcare. The breadth of relevant outcomes studies translates into numerous avenues for investigation. Most of the most important outcomes studies are listed (with annotation) later in this monograph. But first, this section will introduce the methodology of HEMS outcomes studies and consideration of the HEMS association with patient and system endpoints.

First endpoint: Aviation safety

If HEMS is inherently unsafe, then discussion of patient-related outcomes is irrelevant. Aviation risk involves not only patients, but also air medical crews. Although there is risk in any endeavor, any substantial risk associated with HEMS should seriously weigh against using the mode for patient transport.

Fortunately, there are detailed data available to inform the overall adjudication of HEMS risk. There are also superb analyses of the causes of HEMS accidents, and potential avenues for air medical aviation risk mitigation. Many years of ongoing work from experts such as Blumen have informed the aviation safety conversation. This monograph’s author is not an expert on these matters. The following points are offered as brief summary and justification of continued HEMS operations while safety work continues. Since the data tend to be collected on a national basis, the evidence that follows is presented with identification of country from which the analysis was based.

- **Australia**: A 2005 Australian study overviewing a decade of HEMS transports (1992-2002) found that helicopter transports were associated with one patient death per 50,164 missions.
- **Canada**: A 2007 Canadian report takes the route of assessing patient fatality rates per mile traveled. The death rate for HEMS cases was a quarter of that for GEMS transports (0.4 vs. 1.7 patient deaths per million transport miles).
- **Germany**: A 2008 German review comprising six HEMS transport years (1999-2004) found a decreasing crash rate and no aviation-related patient deaths. German follow-up analysis in 2015 supported their case that properly planned and conducted aviation allows safe nighttime operations (traditionally eschewed by many European operators).
- **The Netherlands**: A 2014 Dutch study of a more limited time period, restricted to nighttime flights (n = 513), found zero accidents and concluded that nighttime operations should not be precluded by safety considerations in that country.
- **United Kingdom (UK)**: A 2008 UK report overviewed 5 years (1999-2004) of GEMS and HEMS transport-related fatalities; investigators identified zero HEMS- and 40 GEMS-associated fatalities. More recent (2014) analysis from the UK estimates that over a quarter-century of British HEMS operations the fatal accident rate of .04 per 10,000 missions compares favorably with worldwide fatal accident rates (which are reported to range from .04 to .23 per 10,000 missions).
- **Italy**: A different, service-based approach was taken in the coastal northeastern region of Liguria, where 20 years of neonatal transports by one service were assessed. During the time frame in question, there were zero HEMS crashes and three GEMS accidents (for a GEMS accident rate of 1 in 1600 transports).
- **USA**: One overview from 2007 reports that, based on two decades’ data, there is less than one patient death per 100,000 USA HEMS missions. In 2016, detailed analysis of all USA HEMS-related accidents from 1983-2014 found that while overall accident rates declined by 71% over the past three decades, the injury severity profiles and the fraction of fatal accidents (36-50%) are not changing.

There are caveats to interpreting the above numbers. Different countries’ operations differ in safety-related operational aspects (e.g. whether flights are executed in nighttime or poor-visibility conditions). Less easily measured – but likely more important – are inter-program variabilities in safety culture. The HEMS safety picture is too complex to be easily compressed into bullet points such as the above, but the data presented should be helpful to introduce the topic.
Leaving aside HEMS programs’ heterogeneity and helicopter aviation’s specific areas of debate (e.g. risk-reducing effects of certain pilot training components or use of night-vision apparatus), there remains another major challenge to weighing HEMS safety: lack of GEMS safety data. The lack of this information has stymied even the most meticulous healthcare policy analysts assessing HEMS and GEMS. Delgado has concluded that, given uncertainty regarding GEMS transport-related fatality rates, true comparison of HEMS vs. GEMS transport safety is difficult.

Every aviation incident in the USA (and most developed countries) undergoes intense and appropriate scrutiny at the federal level, but GEMS accident-related death and disability are not similarly tracked. Lack of information inevitably leads to conclusions such as: “Unlike helicopter and fixed-wing EMS incidents, little is known about ambulance crashes.”

The picture on GEMS safety is clarifying. National Highway Traffic Safety Administration (NHTSA) has in recent years began tracking ambulance crashes with tools such as the Fatal Accident Reporting System (FARS). NHTSA reports on its public website (www.ems.gov) that the two decades 1992-2011 saw 4,500 motor vehicle crashes (MVCs) involving GEMS; the agency estimated a mean of 33 deaths per year, related to GEMS. While these data are, as previously noted, not necessarily comprehensive, the NHTSA MVC rates for GEMS are generally in line with a two-year national survey of USA tort claim-related GEMS fatality data presented by Wang in 2008.

What is the bottom line on HEMS and safety? First and foremost, aviation safety should be the prime consideration in all cases for which helicopter transport is being considered. If a mission cannot be conducted within the envelope of acceptable risk – keeping in mind that risk is never eliminated in any transport – the aircraft should stay on the ground. However, blanket statements that “HEMS is risky” are lacking in evidence; such statements oversimplify and border on irresponsibility. HEMS operations – like GEMS operations – can indeed be risky, but the literature shows they can also be safe.

Given data at hand, the conclusions of most policy researchers seem reasonable. First, HEMS must be conducted with meticulous attention to safety at all times. Second, if operations are conducted in a realistically achievable safety envelope, the mortality benefits of HEMS outweigh (on a utilitarian basis) the aviation-related mortality risks. Finally, rational consideration of HEMS transport safety should include the risks associated with transport by non-HEMS means or of not being transported at all.

Clinical outcomes endpoints: Survival

The most important outcome for HEMS studies is survival. If HEMS improves survival, then cost-effectiveness may be established by this endpoint alone. However, it is probable that if HEMS improves survival, there are other unmeasured (but still important) clinical benefits that contribute to a case for HEMS utility.

It’s preferable for studies reporting on survival to include precise endpoint definition. Timing of vital status may be relevant; survival to hospital admission may be less meaningful than survival to hospital discharge. Functional status is also important, since survival in a persistent vegetative state is clinically and economically quite different than discharge home. Many of the more recent HEMS trauma studies (particularly those studies that focus on TBI) specifically address discharge disposition; mention of this endpoint should be specifically sought in a close reading of the literature.

The survival endpoint is clear and objective. Its simplicity translates into relative ease of ascertainment. Researchers using survival as an endpoint don’t need to make a case for the clinical and health-economic importance of decreasing mortality. When the research situation is one for which survival is an appropriate endpoint, the best research question for HEMS investigators is: Does HEMS improve survival?

Clinical outcomes endpoints other than survival

There are potential HEMS benefits separate from mortality reduction. These are considered in this subsection, which provides a partial listing of non-mortality endpoints seen in the air transport literature.

The question of functional status, mentioned above, informs research designs assessing illness and injury with particular functional impact. Traumatic brain injury (TBI) and ischemic cerebrovascular accident (CVA) are situations for which functional outcome is particularly important. For TBI or CVA, restriction of endpoint assessment to survival (without functional assessment), can paint an incomplete picture of HEMS benefits and economics. If flight crew deployment simply changes a scene death to an expensive hospitalization for a patient who never emerges from coma,
there are obvious implications for HEMS’ cost-benefit calculations. The HEMS literature includes studies assessing non-mortality functional status. TBI data illustrate clear links between HEMS deployment, reduced secondary brain injury, and improved functional status.32 With CVA, the evidence is indirect, requiring linkage from HEMS use to time savings to improved neurological outcome.33,34

Analgesia provision is a well-accepted endpoint, with relevance to both patient-comfort and physiology.35 Investigators have assessed analgesia in both trauma and acute cardiac populations.35–38

Other reported endpoints are related to endotracheal intubation (ETI) and the overarching arena of airway management. In both adults and children, overall ETI success,39–41 and first-pass ETI success42 have been assessed. Additionally, peri-ETI physiology measures (e.g., oxygenation, ventilation) have been reported, with particular emphasis on their relationship to secondary brain injury in trauma cases.32,43,44

Other non-mortality endpoints found in the HEMS literature are myriad, ranging from patient-safety error rate45 to endotracheal tube (ETT) cuff pressures.46 The HEMS cardiac literature includes studies reporting cardiology-specific endpoints (e.g., reinfarction).46,47

All non-mortality endpoints share one characteristic: the need for researchers to make a case for clinical relevance. Sometimes, clinical impact is clear (e.g., assessment of functional outcome scores in TBI). Sometimes, though, the clinical impact of a selected non-mortality endpoint (e.g., ETT cuff pressure) is less clear; it’s up to the study authors to convince readers their endpoint is viable. This need to establish the importance of a selected non-mortality endpoint is also a characteristic of the next set of endpoints to be discussed in this monograph.

**Non-clinical outcomes: Systems and logistics**

Trauma outcomes studies benefit from registry-based data sources and well-accepted methods for case-mix adjustment. Large databases bring analytical power (high n); acuity scores allow statistical correction for HEMS cases’ tendency to have greater injury severity than GEMS patients. These methodological advantages, so important in trauma studies, are not available to the same degree for studies in non-trauma populations.

For non-trauma populations, the difficulty in executing large, acuity-adjusted outcomes analysis translates into a greater role for non-mortality endpoints. Some of these endpoints have been mentioned in the previous subsection, but another class of endpoints—surrogate endpoints—is particularly important in non-trauma HEMS studies. The most important of these non-clinical endpoints is time savings.

The key to process (or logistics) endpoints such as time savings, is the ability to tie these non-clinical parameters to morbidity or mortality benefit. Given HEMS’ roots in battlefield trauma evacuation, and given trauma systems’ historical emphasis on time savings (e.g. “the Golden Hour” of Dr. R. Adams Cowley), it may be considered ironic that HEMS time-related endpoints are far more prominent in the non-trauma HEMS evidence base. The twin mantras *Time is brain* and *Time is myocardium* have spawned a HEMS evidence base espousing time savings as a surrogate endpoint in ischemic CVA and ST-elevation myocardial infarction (STEMI) patients.48–51

For certain cases, the process endpoint is minimization of out-of-hospital time, not overall time. As an example, studies of interfacility obstetric transports have focused not on whether HEMS got patients to tertiary care faster, but whether HEMS use allowed for patients to spend less time in the (riskier) in-transit setting.31,52

Other “efficiency” process endpoints have also been reported. HEMS-related process endpoints include facilitation of getting interfacility-transferred aortic aneurysm patients to operating rooms,51 scene-transported TBI53 or CVA44,49 patients to cranial computed tomography (CT), and STEMI patients to cardiac catheterization.55

**Conclusions regarding endpoint definition**

The first endpoint to be considered in HEMS, is aviation safety. If HEMS is inherently too risky, then operations should cease. Available data support continuing HEMS operations with continuing attention to optimizing safety.

For studies of HEMS in the injured, mortality assessment is facilitated by availability of large-scale trauma registry data and (even more importantly) acuity-adjustment methods; the latter are critical to prevent anti-HEMS study bias related to HEMS vs. GEMS case-mix and injury severity differences (i.e., higher crude mortality with HEMS).

Studies of HEMS in non-trauma diagnoses are limited by lesser access to large-scale registries. Even more problematic is HEMS investigators’ inability to measure (or adjust for) illness severity. Non-trauma HEMS studies are thus less likely to assess mortality or functional outcome, and more likely to focus on secondary clinical endpoints (e.g.
chest pain relief) or surrogate endpoints (e.g. time savings).

The assessment of non-mortality endpoints provides potentially valuable information on possible HEMS benefits, but for any endpoint other than mortality or morbidity, HEMS study authors must establish clinical relevance.

Financial endpoints (e.g. cost-benefit analysis) can be calculated only after clinical benefits of transport are known with some certainty; these financial endpoints are thus addressed later in this monograph.
Section 2: Study designs in the HEMS literature

This section outlines types of studies found in the HEMS outcomes evidence base. The opening subsection addresses a commonly noted problem – evidence quality – with HEMS research. Subsequent subsections list different types of research designs used by HEMS outcomes researchers. Illustrative examples of each type of design are provided in order to highlight some advantages and limitations of each methodology.

The randomized controlled trial (RCT)

The well-conducted RCT is widely and appropriately acknowledged as an optimal source for evidence-based medicine. However, there have been only a few attempts at HEMS-related RCTs. Both were terminated early, due to unwillingness of clinicians (referring hospital physicians or prehospital care providers) to allow their patients to be randomized away from HEMS. This type of clinician reluctance combines with a variety of other issues (e.g., ethics considerations) to render unlikely any successful execution of large-scale RCTs that include randomization away from HEMS. The absence of RCT data has been acknowledged as a major limitation of the HEMS evidence base in systematic reviews, but those reviews also note that there is much to be learned from extant studies.²

Expert opinion

While reasonably considered to be a low-level evidence type, expert opinion is not without value. Where RCT data are lacking, consensus statements and judgments of leaders in various medical fields are potentially more important. Of course, the very fact – lack of solid RCT evidence base – that increases the weight of opinion, also contributes to the inevitable nature of diversity in such opinion. Expert opinion comes in a variety of forms. Some examples follow:

- **Editorials**: In a 2003 commentary in *Chest*, the journal of the American College of Chest Physicians, some of the USA’s prominent cardiologists and intensivists wrote “In many communities, emergency air medical systems have become an integral part of the practice of cardiology and critical care medicine. We firmly believe that air medical transport is a safe means for transport of cardiac patients and should be considered for patients who require transfer to more specialized centers for additional diagnostic and therapeutic interventions.” Similar editorial evidence exists for other diagnoses including (but not limited to) trauma, CVA, obstetrics, and pediatrics.⁶⁰
- **Government agency findings**: The National Highway Traffic Safety Administration (NHTSA), the USA governmental body responsible for road safety, convened an expert panel that concluded “Better utilization of air medical services can produce reductions in mortality and morbidity of crashes. Such benefits can be achieved with faster response and transport times, higher quality care at the scene and in transport, and at the highest-level trauma center.”⁶¹
- **Professional association panel reports**: The American Stroke Association Task Force on Development of Stroke Systems identified HEMS as a vital part of CVA care, stating that “Air transport should be considered to shorten the time to treatment, if appropriate.”⁶²
- **Position statements from physician organizations**: A Resource Document for a position statement of the National Association of EMS Physicians (NAEMSP) recommends HEMS transport of stroke patients if the closest fibrinolytic-capable facility is more than an hour away by GEMS.⁶³

Case reports

Like expert opinion, case reports carry limited methodological weight in evidence-based medicine. However, given the unusual nature of HEMS aviation-related capabilities, some case reports are noteworthy for illustrating types of care that HEMS is uniquely situated to deliver.

Usually, the emphasis is on HEMS’ ability to quickly reach patients with some combination of expertise, equipment, or drugs. Examples of such reports follow:
- Scene response for direct transport to tertiary time-windowed therapy: Use of HEMS has allowed patients with diagnoses such as stroke, to bypass GEMS transport to community hospitals (lacking lysis capability) and instead be air-transported to expedited neurovascular intervention.  
- Transport of pharmacologic agents to patients: The HEMS literature includes myriad reports of drugs (e.g. prostacyclin), blood products (e.g. prothrombin complex concentrate), and toxicologic antidotes (e.g. fomepizole, digoxin Fab fragments) that were transported in timely (life-saving) fashion that would not have been obtainable in time had GEMS been used.
- Movement of advanced-level care to patients for whom GEMS access is time-consuming or impossible: HEMS has been reported to be life-saving in various terrains ranging from mountains to coastlines, and in situations in which disasters impede GEMS access.

**Panel review**

In panel review studies, groups of transports by HEMS (and often by GEMS as well) are discussed by healthcare providers who then adjudicate whether HEMS may have contributed to improved outcome. The panel approach is exampled by many studies, particularly from Scandinavia, which use a Delphi technique to work towards consensus.

In comparison to some of the more complex, yet still imperfect, study designs, panel review projects are much easier to execute. Another advantage to these studies is their potential for clear identification of the mechanism responsible for HEMS' salutary effect (e.g. flight crew changes a misplaced airway inserted by GEMS). Of all HEMS study types, the panel review is theoretically among the most likely to provide a direct relationship between a particular HEMS characteristic (e.g. speed, airway skills) and better outcome.

The panel review study has significant limitations. The main weakness of the design is that it is inherently subject to biases, both for whether HEMS truly affected outcome and whether particular HEMS interventions saved lives. It is difficult to conceive that even the most well-intentioned reviewer could completely divorce preconceptions about HEMS utility from the assignation of putative HEMS benefit in borderline cases.

**Patient-safety reports**

Patient-safety studies, which are here considered separate from aviation-related safety, address whether certain populations are placed at particular risk by HEMS transport. Patient-safety studies in HEMS are best considered a necessary, but not sufficient, basis for contention that HEMS is useful; it’s hard to justify the resource investment for most HEMS flights if the supporting case is simply that HEMS is no more unsafe than ground EMS. This research is still important, though, because if HEMS and associated vehicle characteristics (e.g. extra patient transfers, aircraft vibrations) increase risk, then judgments about flying individual patients may be altered.

In general, the HEMS patient-safety studies fall into two categories. The first category addresses issues of potential importance, and outlines whether the hypothetical risks are confirmed in actual series. The second category addresses issues that are judged to be of potential clinical import, and outlines recommended measures to mitigate the risk. Overall, the literature supports a conclusion that HEMS may theoretically involve risks (e.g. related to vibration or altitude) but that flight crews are adept at recognizing and managing any risks that exist. Examples of patient-safety studies include the following:

- Early patient-safety studies assessed whether the electrical or vibration environment of HEMS increased pacemaker or post-thrombolysis complications in cardiac or stroke patients.
- In an unusual extension of these types of studies, one prospective study administered tPA to mice and then transported them via HEMS or GEMS; post-transport analysis for any complications (such as bleeding) failed to identify HEMS risks.
- Another study focusing on vibrations assessed the potential for worsening of neurological deficits in spinal-cord injury patients transported by air. The results suggested that HEMS was actually associated with fewer vibration-related pathological changes than a military ground ambulance comparator.
- Related work on vibrations has suggested some possibilities for fracture-associated bleeding risk, particularly in patients with pelvic injuries, but there was no ground EMS control group. The investigators’ sound recommendation was minimization of vibration-related bleeding risk by proper pre-flight splinting.
• Whereas the previous points addressed potential problems related to vibrations, other studies have focused on the relationship between altitude and physiology. Information from an artificial lung-mimic model demonstrated that (at the altitudes most HEMS flights occur) there is some—although often overstated—potential for clinically significant changes in pneumothorax volume. Other studies have assessed the potential for endotracheal tube cuff pressure changes associated with altitude changes; results’ clinical relevance is not yet known definitively but the studies do add another facet to the special care issues to which flight crew must be attentive.

• Some studies have not assessed particular aviation or other specific risks, but rather examined the overall physiologic stability of HEMS vs. ground ambulance transports. The best of these investigations assess transports by the same medical crew, who execute transport in both air and ground ambulances. Example studies report no increase in adverse outcomes associated with the HEMS setting, for pediatric patients of high acuity.

Time-savings analyses – Trauma

For trauma studies, the subject of time savings has been occasionally confusing. It seems that HEMS’ potential impact on survival does not have reliable association with time savings. From the earliest major HEMS trauma study by Baxt, through more recent data from the USA and around the world, there is no clear-cut line between time savings and survival improvement. While this is likely due to the fact that—at least in some cases—life-saving interventions (e.g. airway management, chest decompression) are provided at the scene, the use of time as a surrogate endpoint for HEMS trauma studies is not well-grounded in the evidence base.

Time-savings analyses – STEMI and ischemic stroke (iCVA)

Although the use of time as a surrogate endpoint is not justified for trauma studies, for non-trauma diagnoses with time-windowed therapies there is argument in favor of assessing a time-savings endpoint to see if HEMS is useful. One of the most important study types in the non-trauma HEMS literature, is reporting of whether HEMS use speeds time to receiving time-critical therapy such as percutaneous coronary intervention (PCI) or ischemic stroke (iCVA) thrombolysis. Closely related is the question as to whether HEMS use allowed patients to receive time-windowed therapy for which they’d been ineligible had HEMS been unavailable. Savings of time is directly correlated to improved outcome for at least two diagnoses: STEMI and iCVA. Examples studies for each of these patient groups are found in the HEMS literature, with studies reporting time savings as a continuous variable and also assessing the dichotomous outcome of “arrived at receiving center within treatment window.”

There is substantial weight in analyses such as one demonstrating that HEMS gets patients to PCI an hour faster than if they’d gone by GEMS, or another finding that HEMS triples the odds of patients’ arriving at stroke centers in time to receive lysis. These types of time-savings studies are thus an important component of the HEMS outcomes literature for these non-trauma populations. HEMS should not be assumed to always result in time savings, but the time savings that can be reaped with HEMS can have important implications for outcome and planning for STEMI and iCVA regionalized systems.

TRISS-based trauma survival research

Scoring systems such as the Glasgow Coma Score (GCS), Trauma Score (TS), and Injury Severity Score (ISS) are useful to stratify patient acuity for injured patients. Given the unadjusted higher mortality risk of HEMS trauma cases as compared to those transported by ground, such acuity adjustment is an absolute requirement for assessing relationships between transport mode and survival.

The basic scoring systems, such as GCS and TS, are familiar. A more complex method, TRISS, is perhaps less familiar but it’s broadly used and generally well-accepted. TRISS incorporates physiologic (TS), anatomic (ISS), mechanism (blunt vs. penetrating), and age (55 years as cutoff) covariates in a logistic regression model with death as outcome. Since TRISS’ applications (and misapplications) are relevant to assessment of the HEMS outcomes literature, a brief overview of the method is presented here.
TRISS’ terms (β coefficients) are derived from the American College of Surgeons’ Multiple Trauma Outcome Study (MTOS) database. As the MTOS database ages, more recent TRISS studies using those MTOS coefficients may be inaccurate; reporting of M statistics (see below) is therefore of increased importance. Some studies utilize variants of TRISS such as the TRISS-L (aimed at reducing bias related to prehospital intubation’s impact on vital signs). These TRISS variants are typically employed in similar fashion to standard TRISS.

Once TRISS has been used to model the anticipated mortality for a study population, the predicted mortality can then be compared to actual mortality. Some important steps must be taken to assure methodological rigor.

For TRISS to work best, there needs to be similarity between the investigator’s study population (i.e. the potential group upon which TRISS will be used) and the MTOS population. It’s not appropriate to employ unadjusted TRISS methodology on a study group that’s significantly different from the MTOS source group from which TRISS coefficients were derived. Therefore, the first step in using TRISS for outcomes analysis is to ensure that the study group’s injury acuity distribution is sufficiently similar to that of the MTOS population to enable use of the MTOS-derived regression coefficients. This is performed by calculating an “M” statistic.

Since M does not follow a statistical distribution, there is no test (i.e. calculation of a p value) to see if M is acceptable. However, a minimum of .88 (on a scale with maximum 1.0) is generally considered to be the threshold indicating acceptable case mix similarity; lower M implies lower acuity than that of the MTOS cohort. Analyses have demonstrated that especially in locations outside of the USA, M statistics are substantially lower than levels appropriate for uncorrected TRISS use.

If calculation of the M statistic denotes appropriateness of TRISS utilization, then a “W” statistic can be calculated. W estimates the number of lives saved for every 100 transports. When further stratification is necessary, or when M < .88, adjusted or standardized W can be calculated.

The last step in TRISS is calculation of a z statistic to test H₀ of no difference between 0 and the calculated W. There are different mechanisms for using the methodology. The most important variation is the use of a control group against which HEMS performance is compared. Many trauma studies use TRISS’ MTOS population to provide a “control” group; in other words, the investigators simply demonstrate that a group of studied trauma patients survived “better than predicted” by TRISS. Obviously, this setup is subject to confounding by patient mix and a variety of other factors (e.g. trauma center quality of care) that may not reflect upon prehospital care.

The most compelling of HEMS TRISS studies are those characterized by simultaneous TRISS analysis on HEMS and ground EMS patients transported to the same receiving center(s). Such an approach reduces potential confounding by factors such as hospital care quality. TRISS can provide strong evidence for air transport benefit if actual mortality is significantly lower than predicted mortality in cases transported by HEMS but the GEMS-transported cases die at predicted frequency. For instance, a province-wide study in Nova Scotia found a statistically significant outcomes worsening (as compared with TRISS-predicted) with ground transport, whereas air transport accrued a 25% outcomes improvement; as compared to the ground transport alternative, HEMS improved mortality by 35%. A 2016 from Ontario similarly found divergent results (i.e. HEMS improved outcome whereas GEMS worsened outcome). The more usual result is that GEMS-transported cases die at the predicted rate, whereas HEMS-attended cases have higher-than-predicted survival.

Observational cohort studies

TRISS is, at its base, a type of observational cohort study (OCS). The cohort of HEMS cases is assessed for survival, and compared to a baseline of either a study-center GEMS cohort or the TRISS (MTOS) cohort. Since trauma is the only HEMS patient population for which there is a worldwide accepted survival model, TRISS is unique in its availability as a tool for HEMS researchers. However, there are myriad other OCS designs that have been deployed by those assessing HEMS’ impact on survival and other endpoints.

Since OCS is one of the most commonly encountered study designs in EM, the analysis for these types of studies has evolved in such fashion as to be too detailed for description in this monograph. Interested readers are directed to the author’s overview of OCS assessment found at www.cctcore.org (subheading: EM lectures). The OCS monograph includes details on propensity scoring, instrumental variables, and other topics that are of particular relevance in HEMS studies.

The most straightforward OCS approaches attempt to match acuity and other characteristics for HEMS and GEMS
patients and then perform outcomes comparisons. The approach that is simplest is an unadjusted outcomes comparison between HEMS transports to a particular center, and outcomes of cases who presented primarily to that center (by GEMS or private vehicle). This methodology tends to be aimed at demonstrating HEMS’ ability to extend the reach of a center’s care to further-distant cases than those to whom the center is readily accessible by ground. These OCS designs have been executed for cardiac, obstetric, and neonatal populations, with findings that HEMS transport of patients distant from specialty centers allows those patients to achieve outcomes equal to those of patients presenting primarily to study centers.

Other OCS designs include attempts to adjust for the fact that HEMS cases – regardless of diagnostic group – tend to be higher acuity than those who arrive at receiving centers by other means. OCS approaches for trauma have employed stratification by parameters such as ISS, TS, injury mechanism, and demographic factors.

The advantage of these cohort approaches is that they employ classical, intuitive, and widely accepted statistical techniques to allow for between-group acuity adjustment (where such adjustment is clinically possible). The primary disadvantage of this type of study is that large populations are usually needed to produce useful results. This is because the outcome of interest – mortality – is infrequently affected by transport mode. In practice, this limitation means that even when a study of this design suggests same-stratum mortality differences between air and ground transported patients, statistical significance is not commonly achieved. Relatively low cell counts (since data are split into multiple tables) translate into low study power and wide confidence intervals that are likely to cross the null value.

In another OCS methodology, investigators use matching to adjust for inherent acuity differences in HEMS and ground EMS patients. This is potentially useful when study n is low, but existing studies are weakened by problems such as residual confounding on unmatched variables (e.g. Revised TS, intubation).

The most common method for analyzing OCS study data in HEMS is to incorporate the transport mode cohorts (air and ground) into a model (usually logistic regression-based) that explores the potential association between transport mode and outcome. One of the modeling problems associated with having relatively low outcomes numbers (i.e. low mortality) is that models often don’t have the ability to incorporate enough covariates; there are so many potential confounders of the HEMS-outcome association that the required 20 outcomes per covariate ends up restricting model power.

OCS model-building tends to employ advanced techniques. Propensity scoring can assess for confounding by covariate patterns. Instrumental variables (e.g. distance from trauma center) can help replicate conditions of an RCT.

### Natural experiments

Although it’s a type of OCS, natural experiment methodology warrants special mention as a study design that can be uniquely positioned to provide insight into HEMS’ outcome effect. Natural experiment designs are not prospectively defined plans, but rather naturally occurring situations in which HEMS availability changes. Whether for mechanical issues, weather problems, or simple aircraft unavailability, sometimes when HEMS is called there are no helicopters available. On a larger time scale, HEMS services may come and go as a regional resource. The crux of natural experiment design is analysis of outcomes in HEMS-transported patients vs. patients who would have gone by HEMS if the service were available.

From the very definition of natural experiment design just given, it’s apparent that the major issue with these studies is selection bias: the “non-HEMS” group must include all of those patients who would have gone by HEMS if the helicopter were indeed available. But what if the referring hospital never bothers to call for HEMS due to obvious unavailability (e.g. due to weather)? What if the lack of HEMS availability means that the referring hospital doesn’t even transfer the patient to the trauma center (e.g. due to travel distances)? The biggest problem with natural experiment designs is that they sometimes fail to assess outcomes in those non-HEMS patients that the investigators never knew about.

Methodology that fails to include the entire population of HEMS-eligible patients predictably finds little or no HEMS-associated mortality difference. Such was the case with the trauma HEMS natural experiment studies from Texas and North Carolina. The Texas findings of no decrease in the post-HEMS era’s trauma mortality hardly came as a surprise, given their findings of significantly shorter transport times and markedly lower injury acuity seen in their trauma patients after HEMS discontinuation. Selection bias meant that patients who would have earlier been flown, were simply kept (and possibly died) at the distant community hospitals. The North Carolina study had more numerous
flaws, not least its assessment of a GEMS cohort that was actually smaller than the n of excluded cases (e.g. those who died at referring hospitals while waiting for transport).

A true population-based study, comprising all injured patients in a given region, gives more useful results. The initial such study was a methodologically rigorous effort from Oregon,112 where there was a situation in which some, but not all, of the state’s referring rural centers lost access to HEMS. Mortality changes before and after the time of HEMS discontinuation were assessed in the “no-HEMS” hospitals (where mortality increased 4-fold) and also in matched hospitals that continued using HEMS (mortality was unchanged). Similar positive findings for HEMS’ mortality improvement were found in another well-executed natural experiment analysis that covered a province in Canada.113

The advantage of the natural experiment type of study lies in its potential to methodologically approximate the optimal (but largely unachievable) study design: the RCT. In actual implementation natural experiment studies fall short of assuring such an ideal, but changes in HEMS availability over large geographical areas provide opportunities for population-based means of assessing HEMS utility.

A few other natural experiment studies have assessed changes in trauma mortality when HEMS availability changes in the direction of added helicopter coverage. In Long Island,114 investigators found that when an additional HEMS unit was added to a geographically isolated area of their trauma center catchment region, the number of HEMS-transported patients out of the region doubled and the regional trauma mortality decreased significantly. Trauma mortality was also demonstrated to decrease significantly with the addition of a HEMS unit into a well-developed Danish trauma system.115

Population-based mortality assessments

One relative of the natural experiment discussion is the population-based analysis of trauma mortality with correlation to HEMS coverage. Trauma mortality in regions with HEMS coverage is compared to mortality in areas that lack air medical coverage but which are otherwise identical. Such research is limited by residual confounding and other problems related to the inability to tease out HEMS’ contribution to mortality differences in disparate regions.

There are some data from population-based studies. Preliminary work by the ADAMS (Atlas and Database of Air Medical Services) group has found a correlation between ready availability of HEMS (i.e. 10-minutes’ distance) and decreased trauma mortality as measured by ratio of fatalities per 1000 injuries (R = 0.70).116 Another population-based study, based in Massachusetts, found that HEMS availability was associated with a 13-22% reduction in trauma mortality.117 Another state-based population analysis, based upon doubling of HEMS assets within a decade in Pennsylvania, found that for scene runs >11 miles from trauma centers there was a 1% worsening in mortality for each mile of increase in distance from the scene to the nearest HEMS base.57

HEMS outcome as an incidental finding

Some interesting evidence suggesting HEMS’ positive effects on outcomes comes from studies that were focused on questions unrelated to transport modality. Conclusions drawn from such studies are necessarily limited due to the fact that the investigations weren’t intending to address HEMS. However, the limitation of “non-HEMS focus” can also be an advantage: these studies tend to be executed by parties with no bias in the HEMS debate.

One example of such a study is a traumatic brain injury analysis from Pennsylvania in which investigators found ETI by HEMS – but not GEMS - MS ETI) improved both survival and functional outcome in patients with head injuries.15 Editorialists16 reviewing the study wrote, “Their data show that out-of-hospital ETI performed by trained flight EMS providers using a rapid sequence intubation protocol was associated with decreased mortality and improved neurologic outcome. This suggests that there may be something in the technical expertise of the flight crew or in the airway management practices after ETI that has potent effects on outcome.”

Another trauma airway study, this one from Oregon,17 also focused on factors other than transport modality but found strong evidence for HEMS-mediated outcomes improvement. In a set of analyses of varying design, the authors report: “Helicopter transport was associated with lower mortality in all transported patients at all distances.” Varying model setups for the Oregon study, which included over 8,000 scene trauma patients transported to Level I care, found odds ratios for HEMS-associated survival improvement ranging from 0.34 to 0.38 (all were statistically significant). As the study’s authors write: “Although this study was not designed to study the impact of helicopter transport, its impact was seen in all three models, signifying that helicopter transport does indeed impact survival in all trauma patients,
not just those with an out-of-hospital ETI.”  

Other types of evidence

While the preceding categories comprise the bulk of the HEMS literature, miscellaneous reports comprise an additional category of “other evidence.” While the weight given to this category tends to be less than that afforded more traditional studies, some mention of this lower-level evidence is warranted.

One unusual design is artificial neural network (ANN) analysis. While potentially prone to biases in setting up the model, repeated ANN iterations that consistently demonstrate HEMS outcomes improvement can be persuasive. As an example, the ANN study reported by Davis identified HEMS (as compared to ground transport) as saving a statistically significant 3.6 lives per 100 transports of brain injured patients with head AIS of at least 3; when analysis focused on patients with GCS 3-8, 7.1 lives were saved per 100 transports.  

There are miscellaneous small-series reports and expert-opinion articles that address the potential association of HEMS with improved outcomes in various patient types. Some examples follow:

- A UK report contended that field thoracotomies performed by HEMS crews contributed to survival.  
- With caveats about expert opinion as an evidence level, it is worth noting the writing of trauma orthopedists who contend that urban HEMS use is justified “particularly for patients with spinal injuries” for reasons of rapid and smooth evacuation. It must be acknowledged that while the notion of smoother rides in helicopters may be situationally accurate, preliminary study suggests that ground transport is quite acceptable for spine injury patients lacking other indications for HEMS.  
- Though the ability to extrapolate from anecdotal experience is limited, every HEMS operator can sympathize with the sentiments of one prominent trauma surgeon who wrote that “We have examples of ‘spectacular’ saves,’ that is, care provided in the field that clearly resulted in a positive result that could have been accomplished in no other fashion.”  

Other reports that are not classically included in the body of “outcomes literature” address endpoints such as analgesia or peri-ETI physiology. These reports’ relevance to the HEMS debate stems from extant literature that points out the areas in question (e.g. analgesia practice, airway management physiology) represent clinical arenas in which GEMS practice is identified as sometimes lacking.

- In the analgesia arena, there is abundant evidence that – often through no fault of paramedics –prehospital pain relief practices for ground transport are far less than ideal. Reports of HEMS analgesia practices are much more consistently favorable.  
- Airway management is another field in which HEMS reports are often more favorable than GEMS studies. Evidence has clearly and consistently related better airway skills and higher ETI success rates with improved outcome, particularly in the head-injured. The advantage is not just related to better ETI success rates; post-ETI ventilatory management is also important. Data from California show that even after GEMS ETI at trauma scenes, brain-injured patients have better outcomes with HEMS transport compared to GEMS transport.  

Case reports, opinion pieces, and surrogate-outcome studies that don’t actually execute direct HEMS-vs.-GEMS comparisons can never provide definitive answers to the HEMS debate. However, given the absence of RCTs, these lower-level evidentiary types can occasionally be useful to those researching the HEMS question.
Section 3: HEMS literature

In an early iteration of this monograph, a few decades ago, this section’s stated aim was to serve as a collection point for all English-language HEMS outcomes studies. The state of the evidence was such that outcomes studies were not easy to find and there was utility in a bibliography. Such bibliographies were ultimately published as part of committee work for the National Association of EMS Physicians (NAEMSP), in NAEMSP’s journal Prehospital Emergency Care.

The first pair of NAEMSP Air Medical Committee literature reviews addressed HEMS use for trauma and non-trauma. These two reviews served as the reference for NAEMSP’s Guidelines for Air Medical Dispatch, which were soon endorsed by the American College of Emergency Physicians (ACEP), the American Academy of Emergency Medicine (AAEM), and the Association of Air Medical Services (AAMS).

Subsequent updates to the HEMS bibliography have been published every few years, with the most recent review covering HEMS literature through 2016. These annotated bibliographies can be found at the website of the HEMS research group CCT CORE (Critical Care Outcomes Collaborative Outcomes Research Effort): www.CCTCORE.org.

This monograph’s author learned a few lessons during two decades of reviewing the HEMS literature. First, it’s impossible to eliminate subjectivity both in article selection (e.g. bias towards English-language publications) and in results interpretation. For this reason, the editorial commentary included with the reviews was always less important than the actual listing of the studies and their major findings. Another pair of lessons balanced each other: it became impossible to keep up with all of the HEMS studies even as on-line searching advances eliminated the need for annotated bibliographies as a mechanism for finding evidence.

With the previously noted caveats acknowledged, this section of the monograph is offered as a historical overview of selected HEMS outcomes studies. Within each diagnostic group, older studies are listed first. The listing is neither comprehensive nor definitive. Nonetheless, it is hoped that the listing of these HEMS outcomes studies by diagnostic group might be useful to HEMS researchers as well as those interested in tracing the evolution of the evidence base surrounding air transport.

Mixed-diagnosis patient populations

This subsection includes some well-known studies, and some lesser-known but arguably important publications, that address outcomes in a general population of HEMS transports. The catch-all nature of the diagnostic groups largely precludes meaningful HEMS-vs.-GEMS outcomes comparisons, but there are useful lessons in these studies.

   - The authors, while highlighting logistics advantages to rural HEMS utilization (e.g. improved availability of ALS in less-populated settings), make a strong argument against HEMS benefit for patients in arrest at time of HEMS activation.

   - Comparing HEMS vs. GEMS outcomes in a diagnostically disparate population is difficult. Due to the methodologic challenges (e.g. use of an non-validated scoring system to generate pooled acuity estimates), the authors acknowledge strong possibility that their negative findings were confounded by higher acuity in HEMS cases.

   - As a follow-up to conclusions of Lindbeck et al (reference #1 above), HEMS utilization can potentially be useful for patients who are post-arrest (i.e. after return of spontaneous circulation).


- This unique approach compared ETI success by GEMS and HEMS, on the same patient set, with the same medications. The HEMS crews arrived and supervised GEMS’ initial ETI attempts (under rapid sequence induction medications administered by HEMS). If GEMS ETI failed, flight crews attempted ETI. The authors averred that physicians bring added expertise to the scene of the critically ill or injured patient requiring airway management; the helicopter was simply the mechanism by which physicians got to the patient. Given literature that increasingly stresses importance of first-pass ETI (in order to minimize physiologic derangement and other risks attendant to airway management), there is clinical import to the authors’ finding of HEMS crew first-pass ETI success rates nearly double those of GEMS (84.5% versus 46.5%).

**Trauma: Scene response**

The main spur for HEMS development in many countries was the concept of scene response to injured patients. Largely because of the sizeable databases maintained around the world in trauma registries, much of the HEMS literature focuses on trauma, and most of these studies focus on scene response.

   - Perhaps the landmark study in HEMS and trauma mortality was this TRISS-based calculation of HEMS mortality effect as compared to outcomes from GEMS cases transported to the same center. Dated ground unit capabilities (e.g. use of esophageal obturator airways) may limit the study’s current applicability, but such limitations do not completely negate the study results: in most locations contemporary HEMS crew capabilities remain more advanced than those of GEMS.

   - Baxt followed his single-center analysis (#1 above) with a seven-site multicenter study. HEMS improved outcomes in all seven locations, with statistical significance achieved in five. There was no GEMS control group (TRISS-estimated mortality was the control); it was thus difficult to identify incremental contributions of HEMS in well-functioning trauma systems.

   - Despite substantial potential for residual confounding by acuity differences (e.g. HEMS patients’ GCS was lower than that of the ground group), the authors made a cogent argument that HEMS has little mortality impact when used in an urban area with rapid GEMS times.

   - In the region where this analysis was conducted, HEMS practice levels were well beyond those of responding GEMS (e.g. ETI occurred in 81% of HEMS patients and virtually none of the GEMS cases). To the extent that its regional prehospital capability characteristics are generalizable, the study shows HEMS can improve mortality in situations where ground EMS capabilities are limited or widely dispersed.

   - This oft-cited study was quite complex, in large part because of trauma system issues that were beyond the control of the authors. For instance, the study discarded most transports to trauma centers and instead found that HEMS transports to non-trauma hospitals was not associated with improvement in outcome. The study’s outcomes validity is questioned by the subsequent finding of Younge et al (reference 7 below) of the inappropriateness of using unadjusted TRISS (as was done by these authors) in the U.K. population. Younge’s study
actually included the cases analyzed in this earlier report (as well as many other cases), but in using the statistically appropriate \( W_s \) statistic Younge found HEMS transports to trauma centers improved outcome.


- In analyzing a large group of low-acuity cases, low \( n \) of mid- and high-acuity patients limits the power of attempts to find whether HEMS impacts outcome. In all eight of the subgroups in the mid-range of injury acuity (TS 5-12 and ISS 2-40), HEMS was associated with survival improvements, but the difference was only significant in two of these subgroups. The authors’ conclusions – that low overall acuity meant need for improved triage – were reasonable. However, having spent years as a flight physician in the rural North Carolina setting of this study (Dr. Cunningham was a respected mentor), this monograph’s author was left wishing there were more discussion of the realities related to limited regional GEMS coverage (e.g. using HEMS service to quickly get ALS to an isolated patient, or to prevent an area’s losing ALS response during long-distance ground transport).

7. Younge PA, et al. Interpretation of the \( W_s \) statistic: Application to an integrated trauma system. *J Trauma* 1997; 43: 511-515.\(^{141}\)

- Complexity may account for the infrequency with which this excellent work is cited. The authors, determining that \( M \) statistic assessment rendered uncorrected TRISS inappropriate for London HEMS data (see Nicholl paper, reference 5 above), found HEMS resulted in 4 excess survivors per 100 patients. Survival benefit could have been due to HEMS, receiving facility characteristics, or some combination of the two.


- Artificially calculated metropolitan ground transport times are frequently used in HEMS studies, but the method warrants particular justification – absent in this report – when employed in a city well-known for traffic snarls. The study’s authors also failed to acknowledge potential outcomes impact related to their own clinical findings (e.g. HEMS crew ETI in cases of failed GEMS airway management). These limitations weakened the authors’ otherwise intuitive conclusion that HEMS utility is low in inner-city urban areas.


- Effect modification is demonstrated in a multivariate logistic regression reporting HEMS effects on survival vary with ISS level. There was no mortality benefit for the lowest (ISS <15) or highest (ISS >61) strata of injury acuity, but for the other three groups HEMS was associated with a 2.1-2.6x increase in survival likelihood. HEMS won’t help the trivially or mortally injured.


- The authors’ thoughtful discussion of their negative results from this analysis of TBI outcome for patients receiving basic life support vs. advanced/HEMS response included acknowledgment of confounding. Interestingly, the study’s TBI-centered results are inconsistent with overall trauma mortality results from a previous paper published by the same group (Nardi et al, reference 4 above).


- In the Netherlands, GEMS transport from the scene is often quick; HEMS is used to transport an experienced physician-nurse team to the trauma scene whence patients are taken to trauma centers by ground (with the HEMS team often in attendance). The Dutch HEMS system, assessed in Rotterdam by these authors, has been consistently found to have significant positive impact on outcome.

• Selection bias crippled this natural experiment, in which investigators found that loss of HEMS from their center was associated with decreases in both acuity and prehospital times. The study failed to track outcomes for patients in the post-HEMS era, who were not transported to the regional trauma center (and instead died at the scene or rural hospital). Mann et al (see reference 3, next section) executed the same study design (but with markedly improved methodology to eliminate selection bias) and came up with much more reliable – oppositely directed – results.

- In one of the more unusual exercises in GEMS time estimation, two physicians teamed with a nurse and a retired paramedic to estimate GEMS transport times for cases stretching back over a decade in an often-congested urban area (the south part of San Francisco Bay). Although the time savings conclusions were thus questionable, the study's finding that HEMS cases benefited a maximum of 23% of patients resonated with what would be expected in an area that had no HEMS triage guidelines. The authors underlined the importance of cooperation of air and ground EMS agencies and their medical directors, with respect to generating policies guiding appropriate dispatch of air medical resources.

- In another contribution from the Dutch (see preceding reference #11 by Oppe et al), this prospective assessment of their model of HEMS scene response with subsequent GEMS transport found mortality benefit compared to the GEMS response and transfer. HEMS was associated with a nearly three-fold survival improvement in blunt trauma patients (OR 2.8, 95% CI 1.1 to 7.5).

- There are sound reasons evaluators of medical evidence are taught to be wary of conclusions that were not part of original study questions. However, especially when the investigation is methodologically rigorous, an "incidental finding" can represent useful and unbiased information. This statewide trauma registry study's objective was to evaluate prehospital ETI, not HEMS. However, the results demonstrating HEMS' association with improvements in survival and functional outcome were relevant to the HEMS debate (as noted in the accompanying editorial to the study). Prominent prehospital editorialists highlighting HEMS' positive outcomes effect pointed out that the mortality and functional outcome benefits from air transport may have been related to airway management or other factors such as speed.

- There are some oddities to the study's methodology, and the usual TRISS-related concerns are present. However, the direct comparison of HEMS vs. GEMS patients, and the fact that the multivariate analysis accounted for most (if not all) relevant confounders, strengthen the authors' findings of a HEMS mortality reduction of 21.4%.

- An assessment of 15 years of scene-transported head trauma patients found that HEMS improved survival and functional outcome (OR 1.9, 95% CI 1.6 to 2.3). Subgroup analyses yielded significant outcome improvements for patients with head AIS 3 (OR 1.9, 95% CI 1.2 to 3.0), AIS 4+ (OR 1.7, 95% CI 1.4 to 2.0), and GCS between 3 and 8 (OR 1.8, 95% CI 1.5 to 2.2). There was no statistically significant improvement for patients with higher GCS scores, but the point estimates were in favor of HEMS for both groups and the wide 95% CIs (indicating low power) were predictable given low mortality in such patients. Prehospital ETI by HEMS crews was found to improve outcome as compared with ED ETI (OR 1.4, 95% CI 1.1 to 1.8) whereas prehospital ground EMS ETI worsened outcome. The ETI findings lay a solid foundation for an argument that some of HEMS' survival benefit
in TBI is mediated by airway management.

   • In a follow-up study to earlier work assessing peri-ETI physiologic parameters, the UCSD group assessed the impact of HEMS vs. GEMS transport of TBI patients undergoing scene ETI (which was performed mostly by GEMS, even for HEMS-transported cases). HEMS was a predictor of survival, and also was associated with 40% improved odds of discharge (to home or rehabilitation facility). The authors judged that outcome improvement was due to less frequent inadvertent hyperventilation in HEMS TBI cases.

   • Although the study’s focus (ISS >15 cases transported with a physician in attendance) limits generalization, there was an important lesson about over-focus on the surrogate outcome of time savings in trauma. Compared to GEMS, HEMS took longer to get to the scene (18 vs. 14 minutes) and stayed longer on the scene (26 vs. 22 minutes). However, TRISS analysis found HEMS was associated with improved outcomes. Airway management may have been responsible: despite similar ISS for GEMS and HEMS cases, ETI was much more common (80% vs. 60%) in the HEMS group.

   • In one of the only artificial neural network analyses in the HEMS evidence base, the UCSD group assessed impact of air transport on outcome of patients with head AIS at least 3. The authors found that, in a number of modeling approaches, air medical response to head-injured patients was consistently associated with improvement in outcome. The outcome benefit was even more concentrated in patients with more critical injuries.

   • Published a few years after Frink’s study (see above #19), the Dutch confirmed that HEMS response may offer advanced on-scene interventions that justify prehospital time prolongation. After the initial univariate analysis confirmed the notion that prolongation of on-scene times increases mortality, the authors found that the outcomes detriment due to longer on-scene times was completely reversed when HEMS was present. The study conclusion was that early interventions from the HEMS crews allow “golden-hour” assessments and procedures to be completed long before trauma center arrival.

   • HEMS deployment based solely on GEMS time (30 minutes) and ACS triage criteria was found to be associated with significant helicopter overuse in southern California. Point estimates for HEMS’ mortality benefit are positive but not statistically significant; associated CIs are wide due to a very low number of total endpoints (just 36 deaths). The low n of deaths also calls into question appropriateness of the authors’ 12-covariate regression model; the rule of thumb is a maximum of one covariate for each 10-15 outcomes.

   • Consistent with previous European reports (see above) that HEMS prolongation of on-scene time doesn’t result in worse outcomes, this Italian group found longer on-scene times for HEMS vs. GEMS cases with ISS >14 and head AIS >3, but also found HEMS to be associated with lower overall mortality (21% vs. 25%) and more likely survival with zero or minor impairment (54% vs. 44%). The authors concluded that reduction in time to advanced care contributed to improved outcome. The study identified reduction in secondary brain injury (e.g. due to better airway and hemodynamic management) as the major mechanism by which HEMS transport resulted in better neurological outcomes.

- The National Trauma Data Bank (NTDB) has served as a data source for roughly a dozen HEMS outcomes studies; this was one of the first (and best). With large numbers (HEMS n 41,987, GEMS n 216,400) the authors were able to adjust for many factors in modeling that identified a 22% mortality benefit associated with HEMS scene transport. The study study’s broad array of covariates included age, sex, insurance status, mechanism of injury, prehospital times (calculated for HEMS due to straight-line travel and assuming 150 mph transport speed; unavailable for GEMS), ISS, GCS, admission systolic blood pressure and respiratory rate, hospital and ICU admission and length of stay, mechanical ventilation duration, ED and hospital disposition, and hospital trauma center designation. In addition to the outcomes advantage, significant findings included high acuity for HEMS patients nationwide (nearly half requiring ICU, a fifth intubated for an average of a week, a fifth requiring urgent operative intervention); the authors wrote that "On a national level, patients being selected for HEMS are appropriately sicker and are more likely to use trauma center resources than those transported by ground ambulance." The study also found, in terms of triage, that ISS dropped off only as distance from the trauma center increased -- so HEMS is being appropriately used to get patients in timely fashion, to trauma centers, for logistics reasons when this is necessary. The study reported another counter-argument to "overutilization" charges: <15% of HEMS patients nationwide, were discharged within 24 hours.


- In a Centers for Disease Control (CDC) analysis of the 2007 NTDB data, the overall n was slightly different from that of Brown et al (reference #24 above) due to differing methodology (e.g. restriction of analysis to adults with stringent exclusions for missing values). Multivariate logistic regression adjusting for age, gender, ISS, and RTS identified a 39% reduction in mortality associated with HEMS. As compared to the Brown et al study, the more-stringent threshold for data availability probably contributed to the CDC group's finding of a greater mortality benefit than had been reported by Brown; missing variables probably bias studies against HEMS.98


- Propensity scoring is an important technique to allow for covariate-pattern balancing; the method can control confounding of treatment selection (i.e. HEMS deployment). In one of the earliest reports using HEMS propensity-score modeling, this population-based assessment from Oklahoma found a 33% reduction in mortality associated with HEMS scene response.


- In a secondary analysis of patients in a hypertonic saline study, there were no HEMS-associated differences in outcomes for TBI or shock cases. The study was not powered for a transport mode endpoint and there was inadequate adjustment for confounders such as transport distance, study site (there were 10 centers), or varying levels of prehospital care. On the one hand, the finding of “no outcomes difference” was the take-home message of the discussants providing the commentary accompanying the paper. On the other hand, those who believe HEMS may improve outcome can highlight the fact that deployment of HEMS to patients who were far more seriously injured and much further from receiving centers, allowed equalization of mortality for closer-in cases with less acuity. TRISS calculations predicted significantly worse survival for HEMS patients in two of the three study cohorts (Shock+TBI and TBI only), but in both of these cohorts the actual survival was similar for HEMS and GEMS patients. The authors concluded that HEMS may overcome limitations of distance and access to specialty care.


- There are few HEMS outcomes studies in the flagship journals of medicine; this NTDB analysis was characterized by methodological rigor expected in a JAMA study. In a quarter-million ISS>15 cases from the 2007-2009
NTDB, investigators from Maryland used multiple approaches to address issues with data quality, confounding, and propensity for HEMS use. Every model found association between HEMS and outcome; the most conservative OR estimates were 1.16 (NNT 65) for patients taken to Level I centers and 1.15 (NNT 69) for patients at Level IIIs. The authors averred that in addition to the mortality findings, there were likely other unmeasured but potentially important HEMS benefits. The study data did not allow for adjustment for crew characteristics, logistics factors, or prehospital interventions. Given the broad readership of JAMA, it was useful that the authors pointed out the impossibility of predicting at the time of triage, which patients would meet their study’s ISS inclusion criterion; the point is all too frequently elided in discussions of HEMS overuse.


- Methodologic challenges account for the relative infrequency with which matching studies are seen in the EM literature. One of the major barriers, overcoming residual confounding, likely combined with low power to contributed to the negative findings from one of the only Dutch trauma studies failing to identify a HEMS benefit. The OR point estimate for HEMS was actually favorable (0.8) despite residual confounding by higher HEMS injury acuity (measured by RTS), but the wide CI crossed the null value.


- Staffing models for this French study setting included physicians in both HEMS and GEMS, but flight physicians came with trauma center experience that translated into more aggressive care in terms of ETI and blood transfusion. In analyzing nearly 2000 injured adults the authors found GEMS was associated with significantly increased odds of death (OR 1.47).


- Stratifying cases by mean distance from trauma center and ISS, Alabama authors found no HEMS mortality improvement. Minimal descriptive or analytic statistics as well as lack of consideration of confounders (e.g. crew expertise, prehospital interventions, injury types, physiologic data) severely restrict the ability to judge this study’s contribution to the evidence base.


- The 2007 NTDB cases with ISS and RTS availability were assessed by these investigators, who repeated the findings of other analyses of similar datasets (this study’s mortality OR for GEMS was 1.78). HEMS benefit was identified for all injury severity levels, although subgroup analysis suggested that HEMS actually worsened outcome for patients who were more physiologically unstable (defined by RTS).


- The definition of ISS>15 as indicating severe injury is so common that a HEMS analysis using a lower cutoff is noteworthy. When inclusion in HEMS analysis was set at ISS at least 9, these German investigators assessing three years of German Level I/II trauma center data (8231 GEMS and 4989 HEMS) found a 25% HEMS mortality reduction. The study thus contributes to the case for lowering the ISS cutoff at which HEMS should be judged potentially useful. Besides its inclusion of patients with “less severe” ISS, noteworthy aspects of the study included the fact that the results remained the same regardless of trauma center level, and the fact that prehospital care attendants were physician-level in both HEMS and GEMS cohorts. HEMS patients were more likely to receive aggressive interventions of endotracheal intubation, thoracostomy, and/or hemodynamic support.


- Like other Dutch studies, the study demonstrated substantial HEMS survival benefit. Focusing on patients with
ISS>15, analysis found that while GEMS patients had TRISS-predicted survival HEMS-attended cases showed an excess 5.4 survivors per 100 deployments.

35. Abe T, et al. Association between helicopter with physician versus ground EMS and survival for adults with major trauma in Japan. Critical Care 2014; 18: R46.3
   - For Japanese National Trauma Data Bank cases with ISS>15, investigators using propensity scoring, conditional logistic regression, and multiple-model testing found HEMS reduced mortality by 23%.

   - This nationwide study demonstrated HEMS improved outcome by a 14% margin that was stable over a decade of transport. Over that same decade, major trauma incidence was unchanged but HEMS use declined by 1.6% each year; the authors expressed concern that HEMS was being underused.

   - Investigators assessing NTDB data used propensity-scored multivariate modeling to assess HEMS’ association with outcome in children with TBI (3,142 HEMS and 12,562 GEMS). HEMS was found to be associated with outcome improvement for transports to both Level I and Level II centers (OR 2.6 for improved survival; W was 6.1).

   - Adding to literature that makes a compelling case for HEMS’ potentially improving outcome in TBI cases, this NTDB study of nearly 210,000 cases found HEMS nearly doubled chances of post-TBI survival (OR 1.8 with W of 5).

   - This superbly designed trial took years of planning, and it would be difficult to imagine how it could have been executed with better foresight. Unfortunately, the reluctance of GEMS providers to allow patients to be randomized away from HEMS virtually eliminated elucidation of outcomes lessons: the study accrued nowhere near the thousands of cases needed for sufficient power given the expected HEMS impact. The authors’ intent-to-treat (ITT) analysis – while favoring HEMS – was underpowered and the results were non-significant. The approach to report “as-treated” data was the authors’ only analytic option, but these positive results (HEMS mortality improvement of 16% with NNT of 6) are subject to criticism as being post-hoc. For some observers, this study appears to be the nail in the coffin for the idea of large-scale trials hoping to randomize cases to HEMS or GEMS.

   - For those who felt the need for an analysis as to whether HEMS offered benefit to patients with isolated foot and ankle injuries, here it is, done well and including a full decade of experience. HEMS doesn’t improve outcomes in such patients.

   - In a registry-based observational study this Dutch group found clear benefit from HEMS response to patients with ISS at least 15. The 3-year study included 1495 GEMS cases and 681 with HEMS assistance. In a multivariate model the authors found that HEMS assistance resulted in an additional savings of 5.3 lives per 100 cases.
   • Korea’s developing trauma system utilizes HEMS for both logistics and as a means to get advanced prehospital physicians to trauma scenes. The relatively small study (HEMS n = 79, GEMS n = 1547) found a significant HEMS outcomes improvement. Using TRISS methods the authors reported a HEMS W of 6.7 as compared to GEMS W of -0.8 (i.e. HEMS W differential from GEMS of 7.5 translating to NNT of 13.3).

   • This interesting analysis began with a broadly sweeping (and equally incorrect) statement that “previous studies have not adjusted for the time and distance that would have been traveled had a helicopter not been used.” The authors took a novel approach that assessed a decade of an institutional trauma registry’s scene-transported patients to determine the impact of geography on outcome. HEMS patients had higher crude mortality (4.1% vs. 1.9%) but HEMS was associated with 30% mortality reduction in models that controlled for non-geographic covariates. However, when geographic covariates were included in the model the benefit associated with HEMS disappeared. HEMS patients were not too low in acuity – only 12% of the air cohort was hospitalized <24 hours. The authors offered the possibility that any HEMS benefit was actually offset by delays in helicopter response and getting to the patient.

   • In another NTDB analysis (years 2007-2010), the author took an unusual approach of defining the study cohort as patients suffering cardiac arrest within an hour of trauma center arrival. There were substantial casemix differences (e.g. blunt vs. penetrating mechanism, ISS) between HEMS and GEMS; propensity score methods were used to adjust for these differences with a subsequent finding of absolute mortality reduction of 1%.

   • In a large German trauma registry analysis of over 50,000 cases (16,000 HEMS), HEMS was associated with 19% mortality reduction. The study joins the growing evidence base using an ISS cutoff lower than the traditional 15, to define severe injury and study inclusion. In fact, the investigators emphasized HEMS was actually most beneficial in their low-ISS (9-15) cases, for which the OR was .66. HEMS was also found to be notably effective for mortality reduction in patients older than 55 (OR 0.62).

   • In another departure from the standard ISS>15 cutoff to define severe injury, this registry-based observational assessment included cases with ISS>11 (387 HEMS and 2759 GEMS) transported to the same receiving center over nearly two decades. As compared to mortality predicted by TRISS-L (a modification intended to reduce bias from prehospital ETI) the authors found HEMS to be associated with 5.2 fewer deaths per 100 transports. As compared to predicted, GEMS was associated with 1.4 extra deaths per 100 transports. The W differential of 6.6 (translating to NNT 15.2) is noteworthy for its applicability to cases with ISS at least 12.

   • In an NTDB analysis, this group focused on pediatric cases (<16 years of age). Propensity-score analysis of 25,700 HEMS-GEMS case pairings identified a 28% reduction in mortality.

   • More NTDB analysis, this time on injured children, confirmed that HEMS saves lives in children with severe
injuries (ISS at least 15, OR .66) but doesn’t impact mortality in less-severe cases. The absolute mortality reduction from 11.1% to 9.0% corresponded to a 19% relative reduction in risk of death.


- Another NTDB pediatric trauma analysis, this time focusing on just those cases transported to Level I/II pediatric centers, reported results similar to those of above-noted studies. HEMS improved mortality (50% mortality odds reduction in classic logistic regression and 30% reduction in propensity-scored regression) despite significant overtriage as retrospectively defined by identification of minor injuries.

Trauma: Interfacility transport

Secondary air transport of trauma has received less attention than scene HEMS response. However, there are some studies that address use of the helicopter to move patients from community hospitals to trauma centers. Investigators examining HEMS for interfacility transports have either excluded scene runs from the analysis (this subsection of studies), or lumped scene and interfacility transports together in varying proportions across studies (see next subsection).


- Classical statistical analysis has since been replaced by complicated propensity-scoring, instrumental variables, and other advanced multivariate techniques. However, the straightforward assessment of trauma outcome stratified by injury severity as reported in this study, has the strength of being intuitive. This study shared with some other investigations, the tandem findings of HEMS mortality benefit and lack of time savings with interfacility air transport.


- Time and evolution of rural hospitals’ trauma stabilization abilities may have eroded the results of this early TRISS study. For instance, in the Georgia setting studied, only 8 of the 31 referring hospitals had 24-hour staffing by physicians. At the time of its publication the study was an important example of the principle that HEMS could potentially be useful for interfacility transports as well as those from injury scenes.


- When selection bias is eliminated by assessing all trauma cases – those transported by HEMS, those transported by GEMS, and those kept at referring hospitals – results can be compelling. In such an all-inclusive and well-designed analysis, Oregonians reported a significant HEMS benefit after covering nearly all of the bases. There was some potential confounding related to overall trauma commitment (i.e. a hospital pulling out of the HEMS network could potentially have lesser overall commitment to trauma care) but this investigation stands as a superb example of the natural experiment design.


- A group of Pennsylvania burn surgeons determined that HEMS benefits some cases but that the resource is overutilized. The contribution of this study to the HEMS evidence base is the authors’ reporting of posttransport discussions with the local GEMS providers who called for HEMS. In acknowledging a HEMS dispatch issue lacking an easy solution, the authors point out that there are non-physiologic determinants of GEMS’ calling HEMS (e.g. ability to pay, need to preserve local ground EMS availability) that have been largely ignored by the scores of HEMS triage studies.


- One of the largest ground-versus-air transport comparisons in the interfacility trauma literature (HEMS n 14,771, GEMS n 60,008), this NTDB analysis followed the same lines as the scene trauma study by the same
authors (see above). Multivariate regression was negative for HEMS survival benefit; the point estimate of 6% improvement in OR had a 95% CI that crossed the null (0.99 to 1.13, \( p = .07 \)). For those patients with ISS <15, HEMS was associated with no survival benefit but the authors speculated that morbidity improvements in this group warranted further study. For ISS >15 cases – 49% of all flights – HEMS improved mortality by 9%. Compared to GEMS, HEMS patients were far more severely injured (e.g. peri-transport deaths 10x higher), and required substantially more resources (e.g. emergency operation 50% more likely operation). Only 8% of HEMS cases were discharged within 24 hours.

6. Borst GM, et al. When birds can’t fly: An analysis of interfacility ground transport using advanced life support when HEMS is unavailable. *J Trauma* 2014; 77: 331-337.\(^{111}\)

- When an investigation excludes more non-HEMS cases – hundreds of whom died while awaiting GEMS arrival for transport – than it actually uses to constitute its GEMS group, selection bias is unavoidable. The finding that HEMS got trauma patients to Level 1 care 95 minutes faster than GEMS was not accompanied by any mortality benefit, but the results simply prove that HEMS won’t improve outcome when assessed against a severely restricted group of “non-HEMS” cases that survive long enough to be driven to high-level care.

**Trauma: Combined scene and interfacility mission types**


- The finding that HEMS use for pediatric trauma saved 11 lives per 1,000 transports was correctly reported by the authors as indicating suboptimal triage. However, in pediatric trauma a lower \( W \) should be accepted as favorable, due to cost-benefit ramifications of saving a child’s life (i.e. saving such a life results in decades of life-years gained). Despite the fact that the study did not rigorously adjust for many potential confounders the \( W \) of 1.1 was one of the earliest demonstrations of HEMS benefit in pediatric trauma.


- Using classical logistic regression, the authors of this multicenter study (including this monograph’s author) examined nearly 17,000 HEMS and GEMS cases and found a 24% mortality reduction associated with air transport. The study adjusted for ISS, prehospital level of care (ALS vs. BLS), and scene vs. interfacility mission type.


- In Germany, for patients injured close enough to trauma centers that GEMS transport to trauma care was logistically feasible, HEMS deployment was found to offer no mortality benefit. As distance from trauma centers increased and the GEMS transport option was limited to getting patients to local facilities (with subsequent movement to Level I care), HEMS use from scene to Level I center reduced mortality by 19%.


- In assessing two pathways for pediatric trauma patients to get to tertiary care, it was found HEMS directly from the scene afforded no benefit over GEMS from scene to referring hospital followed by subsequent HEMS transfer to tertiary care. The authors concluded HEMS should be used for secondary transport after stabilization at referring hospitals, but they acknowledged the likelihood of residual confounding by severity since the study groups were distinctly different (e.g. scene transports were more likely MVC trauma and pedestrians struck).


- Canadian population-based HEMS studies comprise an important part of HEMS’ evidence base. This analysis from a rural maritime province assessed HEMS use in adult blunt trauma cases with ISS >11 (notably, this is less than the usual ISS cutoff of 15). Mortality improved 35% as compared to GEMS and the difference in \( W \)
between HEMS and GEMS was 8.8. The study is particularly strong given its inclusion of every trauma patient in the province who was transferred to tertiary care.

   - Published 7 years after the well-done HEMS natural experiment by Mann *et al* (see above), this study assessed trauma mortality in a discrete population (eastern Long Island) before and after addition of a HEMS unit. HEMS’ addition to the system was associated with mortality reduction of 26.5%. Air transport to the regional trauma center increased by 130%, with a commensurate decrease in community (non-trauma center) hospitals’ providing care for injured patients. Interestingly, interfacility HEMS transports from the community hospitals remained stable (*i.e.* there was no increase in HEMS utilization for interfacility transport; the increased utilization was for scene flights).

7. McVey J, et al. Air vs. ground transport of the major trauma patient: A natural experiment. *Prehosp Emerg Care*; 2010; 14: 45-50.113
   - Province-wide database studies are superb methods to eliminate selection bias: all trauma cases in a province are included regardless of transport modality or hospital location. In one of the best such population-based studies, Canadian adult trauma patients were split into 3 groups: Group 1 consisted of adults HEMS-transported to a trauma center. Group 2 patients were those who were initially triaged to HEMS (*i.e.* accepted by the online Medical Control Physician for air transport), but who were GEMS-transported (*e.g.* weather or aviation issues). Group 3 included all other GEMS cases. The natural experiment was successful in that there was no difference between Group 1 and Group 2 with respect to mean age, gender, percentage with blunt injury, AIS, and ISS; Group 3 was of lesser acuity. There was no difference in the time between injury and trauma center arrival, between Group 1 and Group 2. As compared to Group 2 patients (whose mortality was equal to TRISS-predicted), Group 1 status was associated with significant survival improvement (5.61 more lives per 100 transports). Group 3 patients had the worst outcome, with a survival less than that predicted by TRISS (*W* = -2.02).

   - Over a single decade, HEMS assets in the study state – Pennsylvania – more than doubled. In a meticulous statistical approach investigators identified an association between trauma mortality and distance between geographic injury location and the nearest HEMS base; the association reached significance once the trauma scene was more than 10 miles from the nearest trauma center. At 11 miles and further from the trauma center, there was a 1% increase in mortality for every mile distance to the nearest HEMS base. There was no association between mortality and extra HEMS bases (*i.e.* more than one) and there was no HEMS-base effect on mortality for interfacility transports.

   - This Danish study adds to the solid natural-experiment evidence base suggesting HEMS improves outcomes. Of course, a natural experiment design is not an RCT, and it is possible that other factors (*e.g.* improved overall trauma care) occurred simultaneously with the introduction of HEMS. With that caveat, the survival doubling (risk ratio 2) occurring for ISS >15 cases after HEMS introduction translates into a favorable NNT of 7 (*i.e.* one life saved for every 7 HEMS transports as compared to GEMS). Furthermore, HEMS transport from the scene was noted to achieve reduction in need for secondary transfer; this finding has cost-effectiveness implications since that initial stop at the community hospital costs time and money.

    - At a renowned Level 1 center in Georgia, analysis of 14,440 trauma cases found that HEMS was associated with reduced mortality (OR 0.41). The authors also found that HEMS-transported patients were significantly more
likely to be high acuity (e.g. GCS was lower for HEMS, ISS for HEMS patients was nearly twice the GEMS median of 9) or require major interventions (e.g. airway management, massive transfusion, operation, ICU admission). The study had limitations (e.g. including in the analysis private-vehicle transports) that were acknowledged by the authors, and which may have contributed to the fact that this paper’s estimate for HEMS’ mortality benefit was substantially higher than that of the bulk of the literature.

   • In a decade of pediatric patients evaluated by trauma services at two Level 1 centers, using methodology that included geographical (time/distance) information and acuity measures, HEMS had no impact on mortality. Furthermore, 22% of the transported patients had low ISS (below 10) and were hospitalized less than a day. Interestingly, the study also found that, depending on adjustment for geographic variables, ground transport had a “protective” effect in its association with shorter hospitalization duration; GEMS was associated with a 53-69% decrease (depending on model) in hospital days. The authors postulated that HEMS interventions at the trauma scene may be causing complications and thus increasing hospitalization times for the air-transported cases. They also offer the possibility of residual confounding, since the air-transported patients were far more severely injured than those who went by ground. Some of the authors’ points about potential HEMS crew harm at the scene are ironically extrapolated from the GEMS literature (e.g. on airway management) with no supporting data in the HEMS evidence base. However, conclusions about pediatric HEMS overtriage in the study area are more soundly base. The failure to include any point estimates, much less 95% confidence intervals, for the impact of transport mode on outcomes does not help the framing of this paper in the overall evidence base.

   • This large-scale analysis of over 180,000 HEMS and GEMS transports focused on changes in HEMS dispatch criteria implemented in stages over the study time period. As such, the main point of the study dealt with improving triage. The authors found that HEMS triage improvements resulted in 49% reduction of HEMS deployment with a concomitant increase in GEMS utilization. HEMS W was calculated on a weekly basis and graphed over the entire study period. The reduction in (unnecessary) HEMS use did not impact the fact that HEMS improved outcome, thus making the case for better triage (i.e. reducing HEMS use but keeping the resource deploying for those who need it most). HEMS’ W mostly ranged between 2 and 3 over the study decade, and HEMS’ mortality improvement was significantly better than TRISS-predicted and also higher than GEMS-associated mortality improvement.

Cardiac

Some early HEMS programs, particularly in the USA, included an emphasis on cardiac transportation for tertiary care such as primary PCI. As the ties between time savings and improved outcome become more clearly understood, there is a proportionate increase in studies of HEMS’ logistics contributions to cardiac care networks.

   • This early report went far towards establishing the safety – at least with respect to bleeding complications – of HEMS transport of patients after thrombolysis administration.

   • Interhospital transport of acute cardiac cases was found to be both safe and feasible, even for unstable patients. Streamlining of interfacility transport operations can significantly extend the coverage area of a primary angioplasty center.
   • Although most of the patients in the “Air PAMI” trial actually traveled by ground, this study introduced the case for use of HEMS as a component of early transport of patients for primary PCI (rather than lysis at the referring hospital). The study’s results were surprising: despite the transported group’s having triple the time to definitive therapy (155 vs. 51 minutes), interfacility transfer for primary PCI was associated with a six-fold improvement in the composite outcome.

   • A before-and-after study reported improvements associated with instituting a new triage and HEMS transfer system. Contributions specific to HEMS were not able to be elucidated, but transport protocol changes included measures intended to speed patients on their way to PCI. Infusions of heparin and nitroglycerin were eliminated and referring physicians made a single call to activate both HEMS transport and receiving-center PCI teams. The overall time savings of 100 minutes included a HEMS dispatch streamlining of 19 minutes and the data suggested an additional 10 minutes’ time savings from bypassing the receiving center’s ED. The proportion of patients with door to wire-crossing times <90 minutes increased from 0% to 24%; the % with times <120 minutes increased from 2% to 67%.

   • Time savings accrued with HEMS as compared to GEMS were estimated using what is becoming a standard geographical information software (GIS) approach. In the southwestern USA state of Oklahoma, 59 was calculated to be the number needed to treat (transport by HEMS vs. GEMS) in order to save a single life solely due to time savings. The study was designed as a pilot validation for a larger multicenter trial (see reference #8 below) that eventually confirmed the preliminary findings.

   • Using methods reminiscent of some of the early trauma literature, the authors of this review of 101 STEMI cases conclude that HEMS improved outcome based upon the capability of the aircraft to extend the reach of primary PCI. The patients, who were all flown from offshore island locations, comprised a group for whom surface transport was simply not an option. In a sense, the study doesn’t add too much to the literature due to the inevitable lack of precise controls for acuity and casemix. On the other hand, it’s hard to dispute the favorable cost-benefit for these 101 individuals who received timely PCI solely due to the presence of HEMS; depending on how one calculates the benefits (as discussed in a later section) this group could account for substantial return on investment in HEMS.

   • Using time as a surrogate endpoint, these Belgians examined use of HEMS as a mechanism to get STEMI patients to PCI more quickly. In a 5-year analysis of 342 STEMI patients transported for primary PCI by air, HEMS times were compared to software-generated GEMS times. The characteristics of the rural location were such that HEMS was faster in primary response time (11 vs. 32 minutes) as well as transport time (12 minutes vs. 50 minutes). Overall, the median system time gained by HEMS was calculated to be 60 minutes (interquartile range, 47-72 minutes), which time savings corresponds to substantial improvement in mortality (see discussion elsewhere in this monograph).

   • A multicenter assessment of time savings associated with HEMS transport to primary PCI identified a number needed to treat (transport by HEMS rather than GEMS) of 3, in order to get one additional patient to PCI within a pre-defined 90-minute window. HEMS saved a median of 32 minutes over GEMS, correlating to substantial
mortality benefit as discussed elsewhere in this monograph. HEMS was also appropriately used, with over 91% of air-transported cases arriving at PCI within 120 minutes of aircraft dispatch.

   • The goal of this study was actually assessment of crew configurations (physician-staffed HEMS had better outcomes). From an overall HEMS outcome perspective, the relevant study data were those identifying a mean time from EKG to PCI of under 120 minutes for the entire set of nearly 400 cases.

Neonatal

Neonatal care tends to be highly regionalized, and critically ill newborns are often quite unstable. Therefore the HEMS literature on this subject usually focuses on incorporation of HEMS into networks of care as a safe means to bring the sickest infants to the most specialized centers.

   • The authors executed a descriptive analysis of air and ground neonatal transfers, concluding that HEMS was a critical part of regionalized neonatal critical care. While the study is limited by inability to focus on HEMS’ particular contribution, the authors make a solid case for HEMS as a part of a successful regionalized neonatal network.

   • A large-scale, population-based, descriptive analysis of 256 neonatal transports in central Norway found neonatal mortality of the HEMS cohort to be similar to that of non-transported neonates cared for at the tertiary center. Results included findings of occasional performance of life-saving interventions. The authors reported that physiologic parameters associated with oxygenation, ventilation, and circulation all improved during the HEMS transport time frame.

   • There is no difference between air or ground transport (by the same team, into Miami Children’s Hospital) with respect to intra-transport need for cardiopulmonary interventions; there was also no difference in risk of intratransport development of hypocapnia or hypercapnia. In essence, the study showed HEMS is not associated with inherent and unmanageable physiologic risks (e.g. due to altitude changes).

Neurology & Neurosurgery

As a time-critical set of illnesses, neurological conditions are among the most likely to benefit from time savings that can potentially be accrued with air transport. The evolving literature, particularly in the field of iCVA, is characterized by a focus on logistics that parallels the evidence base exploring HEMS uses for PCI patients.

   • This was primarily a “safety study,” demonstrating HEMS transport of post-lysis stroke patients did not result in worsened outcome (e.g. from vibration-induced hemorrhage).

   • While the title may overstate the results – there was no demonstration of outcomes improvement as compared to a GEMS cohort – the authors make an excellent point about the minimal “packaging” needed for iCVA cases. If time savings is the endpoint of focus, iCVA cases represent a group for whom HEMS’ logistics advantages may be truly important (depending on what therapy will be offered at receiving centers).
   - In rural southeastern USA, HEMS scene response for suspected iCVA was found to be appropriately deployed and not overused (stroke was ultimately diagnosed at the receiving center in 76% of cases). During the study period, iCVA transports comprised 4% of HEMS volume but HEMS iCVAs accounted for 23% of receiving-center lysis cases. With proper prehospital provider education and judicious triage, HEMS can extend the reach of a stroke center along the lines of the trauma care model.

   - This retrospective review assessed trauma, cerebrovascular, tumor, and other neurosurgical HEMS interfacility transports into the Massachusetts General Hospital (the study group includes colleagues of this monograph’s author). The approach of retrospective calculation of ground transport times using GoogleMaps is well-executed and since validated (see discussion elsewhere in this monograph). Although the study lacked any GEMS comparison group, the findings (e.g. lack of need for urgent intervention in a third of cases) were sufficient to support a conclusion regarding need for triage improvement.

   - Air transported post-lysis iCVA cases arrived at the receiving stroke center 15 minutes faster than those going by GEMS, but the time savings has questionable clinical significance. Once the iCVA patient has been lysed, presuming there are no plans for further definitive treatment (i.e. mechanical neurointervention) the medical priorities (e.g. blood pressure control,) don’t dictate a need for routine HEMS deployment.

   - In studies of transport for iCVA, one endpoint is whether patients actually receive thrombolytic therapy. The implication is that transport must be effected in such fashion as to get patients to stroke centers within the intervention window. Using data from their national iCVA registry, this study’s authors found that as compared to GEMS, HEMS transports from either scenes or referring hospitals allowed for higher thrombolysis rates. Scene HEMS response was associated with the highest chances of patients’ receiving thrombolytics within the pre-defined preferred time frame of 90 minutes from symptom onset.

   - Time savings is an appropriate surrogate endpoint for transport studies of some patient groups (including cases of iCVA). The authors examined iCVAs going by GEMS (with transport time >30 minutes) or HEMS to a regional stroke center. Results including 265 GEMS and 65 HEMS cases identified longer average transport distances (83 vs. 67) for HEMS and commensurately longer times for air transports. Outcomes were similar and it appeared HEMS saved minimal time. The authors reasonably concluded that expedited GEMS transport of iCVA to lysis centers is preferable to HEMS if the latter does not save time.

   - These Georgians assessed use of hemiparesis to trigger helicopter transport in their center’s rural catchment area in the southeastern USA. Of the patients transported directly from the scene with suspected stroke, 60% had iCVA diagnosed and time-critical acute therapy (lysis or neurointerventional care) was used in 47%. The median first medical contact to groin puncture was 101 minutes (faster than if HEMS had not been used). The authors concluded that use of hemiparesis as a prehospital screening tool for HEMS scene dispatch could be effective in speeding therapeutic interventions and outcomes in patients with iCVA.

- Following on the principle of using HEMS to transport physicians to patients, this proof-of-concept report outlined a case in which time interval from decision to treat and groin puncture was 43 minutes. The authors from Johns Hopkins make a case for stroke systems to include capability for HEMS to quickly transport neurointerventionalists to appropriately equipped community hospitals where rapid treatment can then occur.


- This safety study focused on patients who ultimately were diagnosed with subarachnoid hemorrhage. Investigators compared outcomes of HEMS scene-transported cases going directly to tertiary care vs. outcomes of cases GEMS-transported to nearby community hospitals before undergoing secondary HEMS transport to tertiary care. The authors found the HEMS cases were higher-acuity, but had similar survival and no apparent risk of intratransport deterioration or worsened physiology as a result of HEMS bypass of closer facilities. The authors concluded that HEMS potentially had a role for scene responses to suspected subarachnoid hemorrhage.

**Obstetric**

Obstetric cases bring some different characteristics to transport decision-making. Minimization of out-of-hospital time and use of the mother’s womb as the “best transport mechanism” are among the principles guiding HEMS deployment for pregnant patients.


- As compared to post-delivery transport, antenatal transport improves outcomes, so there is a case for obstetric HEMS flights if patients would otherwise have to deliver at community hospitals. In southern California, HEMS saved substantial time (by avoiding traffic congestion), and neonatal outcomes for HEMS-transported patients were as good as outcomes for cases presenting primarily to the tertiary center. Availability of HEMS increased chances of delivery at the maternal-fetal center: in 25/100 cases the referring physician indicated that if HEMS were not available they’d not have allowed laboring patients to travel by GEMS and would have instead delivered patients at the community hospital.


- In a safety study reporting that the air transport environment was not detrimental in obstetrics cases, this report concluded that maternal-fetal risks associated with HEMS transport are “at most, minimal.”


- Japan has limited tertiary care facilities for maternal-fetal medicine, so maternal (prenatal) transport by air is an important part of regionalized care. The study assessed 26 obstetric HEMS transfers. Using actual air transport times, and estimated ground transport times, the authors calculated HEMS use was associated with savings of 101 minutes’ out-of-hospital time (median flight time, 24 minutes; median estimated GEMS time, 125 minutes).

**Vascular**

The major-vessel HEMS diagnosis that arises most often in HEMS transport is aortic pathology. There are some series assessing HEMS transport of aortic dissection but these data tend to focus on treatment aspects rather than outcome.192 The more common vascular diagnosis in the HEMS non-trauma vascular literature is aortic aneurysm, which has a time-critical nature similar to that of major-vessel traumatic injury.

• This was one of the earliest descriptions of the “direct-to-OR” transport for non-trauma diagnostic groups. This type of expedited care, though difficult to assess statistically, seems likely to occasionally benefit patients since there’s not much that can be done outside of the OR.


• It’s feasible and occasionally useful for HEMS crews to sometimes bypass receiving hospital EDs in order to bring cases directly into the operating room. The ready access of referring hospitals to CT scans translated to 100% accuracy in correctly identifying patients with ruptured AAA.
Section 4: Potential HEMS benefits supported by evidence

The variety of potential benefits perceived with HEMS is illustrated in a New Zealand survey of requesters of air transport. In half of the cases, time was the main factor for HEMS activation. In a third, geographic access was key. For the remaining cases, flight crew expertise was the aim of those calling for HEMS.194

This section of the monograph attempts to bring together the evidence addressing the myriad possible HEMS benefits. Any conclusions are necessarily preliminary, given the non-definitive nature of existing data. However, HEMS is in wide use today, all over the world. Decisions about if and how HEMS is to deployed must therefore be made now, even in the setting of a suboptimal evidence base.

Mortality improvement as an endpoint

Overview
Studies that directly assess HEMS vs. GEMS outcomes using the endpoint of mortality are covered in this section. As noted elsewhere, most of the data that directly measure mortality as a function of transport modality are in the trauma literature. For non-injured patients, particularly those with stroke or STEMI, there are some preliminary data.

Trauma
Historically, the concentration of the HEMS evidence base on trauma translated into emphasis on the endpoint of survival. Studies tended to use registry-based methods (e.g. TRISS) best suited for a mortality endpoint. Unfortunately, methodological heterogeneity in the HEMS trauma literature renders meta-analysis difficult, if not impossible.2 Studies including all trauma transports are quite different from investigations including only cases with a certain ISS cutoff, and the ISS issue is compounded by different investigators’ employment of varying ISS cutoffs to define study groups.

Analyses focusing on various subgroups (e.g. TBI, pediatrics) comprise their own subsets of the HEMS trauma literature. These studies’ findings (e.g. influence of ETI on outcome) may not be appropriate for extrapolation to the broader group of all injured patients.

An additional challenge in the collective summary of the HEMS trauma literature is that some of the best studies assess use of HEMS as part of a wider trauma system; it can be difficult to parse HEMS’ incremental effect (if any) from the systemwide factors.112,141

With the above caveats in mind, the preponderance of the literature as outlined above supports a conclusion in favor of mortality benefit for HEMS use in trauma. While the weight of the evidence addresses scene HEMS use there are sufficient data supporting interfacility HEMS benefit to justify inclusion of these patients in the general group of injured cases in whom HEMS may be useful. At the minimum benefit range, particularly for the general population of injured children, the proportional mortality reduction is as low as a few percent. For the broader population of trauma cases as currently triaged to HEMS, air transport’s mortality reduction varies with particular population characteristics but is likely in the range of 10-30%. A rough estimate for the range of W is 1 to 10.

Given the above, the phrase “there is controversy regarding HEMS benefits,” ubiquitous in HEMS trauma studies’ introduction sections, is most applicable to questions about degree of benefit. Although the available evidence base supports a conclusion that there is mortality benefit with HEMS as currently deployed – in other words, HEMS as dispatched today, using suboptimal triage – there is much work to be done in the realm of triage; this subject is addressed later in the monograph.

Non-trauma
Trauma-centered HEMS literature may tend to focus on mortality with less information on mechanisms underlying putative survival effect, but non-trauma HEMS evidence has the opposite problem of emphasizing endpoints other than survival. The abundant, if mixed-quality, data addressing HEMS outcomes in non-trauma include few studies directly examining transport mode and its effect on survival. The literature that does exist is largely restricted to safety studies and demonstrations of survival equivalence for patients distant from tertiary care.

The first category of non-trauma outcomes studies is the safety study. These analyses address whether there is
increased mortality due to physiologic dangers (e.g. vibrations, altitude) inherent in HEMS’ in-flight setting. The conclusion based on available information is that there is no reason to suspect such risks. For widely disparate populations ranging from neonates to post-lysis iCVA and STEMI cases, HEMS transport is not associated with concerning physiologic derangement or increase in mortality.\textsuperscript{72,83,185,195}

Besides the safety studies, the other mortality-related endpoint for HEMS transport of non-trauma is demonstration of equivalence in outcomes for patients distant from tertiary care, as compared to those presenting primarily to tertiary centers. These types of studies are in essence aiming to show that HEMS extends the reach of specialty care centers, allowing those at geographically distant locations to benefit from the same survival benefits as those patients who live close to high-level care. Data suggest HEMS can successfully extend specialty-center survival benefit to a variety of non-trauma diagnostic groups including neonates, high-risk gravida, and those with STEMI.\textsuperscript{31,103,104}

The final category of non-trauma studies of HEMS’ mortality impact, studies assessing mortality as part of a composite endpoint, includes few data. Perhaps the best example of this category is the AIR PAMI trial, in which STEMI cases transported for primary PCI had a six-fold improvement as compared to non-transported cases (lysed at referring hospitals). The AIR PAMI transport cohort’s improved outcome occurred as measured by a composite outcome that included survival.\textsuperscript{47} This is a less-commonly encountered endpoint in the non-trauma literature, and even AIR PAMI (despite its name) assessed a largely ground-transported interfacility cohort. There is thus insufficient available information to draw even preliminary conclusions regarding HEMS’ impact on composite endpoints that include survival.

For non-trauma populations, the dearth of direct assessments of HEMS’ survival influence will not be resolved until there is a reliable method to adjust for differential acuity in HEMS vs. GEMS cohorts. In the meantime, HEMS’ non-trauma literature offers just a few limited mortality conclusions:

1) HEMS is not associated with unmanageable in-flight medical risks that decrease survival,
2) HEMS can extend the survival benefit associated with tertiary care to geographically distant patients, and
3) The best case for mortality benefit associated with HEMS transport of non-trauma cases lies in consideration of non-mortality endpoints closely linked to survival. These endpoints are addressed in the next subsection.

Clinical outcomes other than survival

Overview

When mortality studies are lacking, non-mortality endpoints provide the next-best endpoint set in an examination of HEMS mode. Even in the trauma population, for which there are data directly addressing mortality effect of transport mode, non-mortality endpoints can provide useful and complementary information (e.g. by suggesting mechanisms for HEMS survival benefit). Some non-mortality clinical endpoints are well-accepted as independent outcomes measures that could justify HEMS use.\textsuperscript{48}

In fact, commentators have remarked that when assessment of HEMS’ clinical effect is restricted to mortality analysis, a major part of the transport-mode effect on outcome is excluded.\textsuperscript{196} In the realm of trauma, for example, those considering the weight of the evidence in favor of HEMS’ improvement of mortality have concluded that if HEMS improves mortality there are likely considerable non-mortality outcome gains as well.\textsuperscript{48,61,154} Thus there are sound reasons to consider what non-mortality benefits may be achieved with use of HEMS.

Functional survival

Within the group of patients whose survival is effected by HEMS, one important question regards functional outcome. If HEMS is saving lives only to increase the number of neurologically non-functional survivors – remember high-dose epinephrine for cardiac arrest? – then argument in favor of air transport is actually reversed. Fortunately, findings from large-scale trauma studies from nearly two decades ago “refute the hypothesis that only the most severely injured patients with a low quality of life benefit from helicopter trauma team” deployment.\textsuperscript{144}

More recent trauma studies have also specifically demonstrated improvements in functional outcome (e.g. discharge to home).\textsuperscript{15,86,127} Non-mortality clinical outcomes have also been specified in the HEMS STEMI literature.\textsuperscript{47} Functional survival is also clearly linked to the logistics (time-savings) endpoint to be subsequently discussed for iCVA transport.\textsuperscript{33}
Airway management

Prehospital airway management, specifically ETI, is a complex subject. Performance of ETI is not universally accepted as an outcome for HEMS studies. Some investigators failing to find HEMS benefit have theorized that flight crews’ higher propensity to perform ETI actually worsens outcome.80 Such reasoning is flawed, since data demonstrating outcomes detriment from prehospital ETI apply to GEMS (not HEMS) airway management. Because of the importance of airway management in acute care (failed ETI is a well-known cause of preventable death),197 and because of the disparity in apparent impact of prehospital ETI when performed by HEMS as compared to GEMS, further attention to the subject is warranted here.

This subsection addresses four major findings regarding prehospital ETI. The overarching lesson from the evidence is that with HEMS vs. GEMS, ETI is more likely, success rates are higher, and peri-ETI oxygenation, ventilation, and hemodynamics are more stable. The preponderance of available evidence supports the conclusion of individual researchers and groups such as the Oxford Centre of Evidence Based Medicine, that airway management is one of the major pathways by which HEMS improves outcomes.18 The reasons for ETI as a mediator of HEMS’ improved outcome are four-fold:

1) Even after adjustment for acuity and other factors, HEMS is more likely to perform ETI than GEMS. In a rural trauma setting, ETI was performed in 81% of HEMS and virtually never in GEMS.130 Even in more urban settings (Germany) in which GEMS crews included physicians, ETI was 33% more likely in HEMS vs. GEMS cases (the difference in airway management was deemed a likely mechanism for the study’s finding of markedly improved trauma survival with HEMS).149 Others in Europe studying HEMS and GEMS in settings where both modalities were physician-attended have also identified frequent ETI in the HEMS cohort.155,158

2) Compared to GEMS crews, flight teams have higher 1st-attempt and overall success rates for ETI. For both adults and children, HEMS crews demonstrate ETI success rates that rival those achieved in EDs, whereas there are lesser success rates with GEMS ETI.13,15,32,41,127,148,198-200 It seems likely that poor results from GEMS ETI are related to provider inexperience and differences in initial and ongoing training opportunities afforded GEMS vs. HEMS personnel.13,15,201,202 Experience differences are highlighted by authors of studies demonstrating ongoing high ETI success rates for HEMS that is often (but not always) physician-staffed. Some illustrative reports include the following:
   o In 2014, a 16-month experience of a U.K. physician-based flight crew newly introduced to a rural trauma catchment found a 100% ETI success rate.203
   o Another 2014 report covering five years of airway management by a physician-crewed Dutch HEMS service compared HEMS and GEMS ETI success in the same patients, for whom HEMS administered ETI drugs and then GEMS attempted one ETI pass before HEMS crews took over. The Dutch found 1st-attempt ETI success significantly higher for HEMS (85% vs. 46%).204
   o In 2015, an Australian group reported 100% ETI success rates by their paramedic-staffed HEMS crew, for both adult and pediatric patients.205
   o Two years after the above study, another Australian group reported in a group of pediatric cases (n = 82 cases over 64 months), an ETI success rate of 100% with 1st-attempt success in 91%.206
   o A five-country European research group combined with Australian investigators in 2015 to report HEMS physician ETI 1st-attempt success rate of 86%, overall ETI success rate of 98.8%, and successful airway establishment in 100% of cases.207
   o In a 2016 report, Swiss physician-staffed HEMS ETIs were characterized by 1st-attempt success in 96.4% of cases and overall ETI success rates were 99.5%.208
   o Another 2016 Swiss study analyzed 425 pediatric ETI cases, reporting 1st-attempt ETI success of over 95% with nearly 99% overall ETI success.209

3) In TBI, there is evidence suggesting GEMS ETI worsens outcome while HEMS ETI improves outcome. There are many studies identifying improved TBI outcome for HEMS as compared to GEMS.127,161 Studies assessing HEMS vs. GEMS ETI performance and TBI outcome have been executed worldwide, with similar results:
   o Prehospital ETI in Pennsylvania worsened TBI outcome when performed by GEMS, but HEMS performance of the procedure improved survival.15
   o The same findings – worsened outcome with GEMS ETI and improved survival with HEMS ETI – have been reported from California.148
Studies of peri-ETI physiology in patients subject to secondary brain injury have suggested that as compared to HEMS, GEMS airway management is much more likely to be characterized by hypoxemia, hypocapnia, or hypotension.\textsuperscript{43,124,125,127,210}

4) Even when GEMS performs ETI, HEMS’ post-ETI ventilation practices improve outcomes (particularly for TBI cases). In a California analysis of patients undergoing prehospital ETI (mostly by GEMS), subsequent transport by HEMS (vs. GEMS) was associated with 40% improved likelihood of discharge to home or rehabilitation facility; intratransport ventilatory practices were judged responsible.\textsuperscript{127} Related studies have found differences in HEMS vs. GEMS capabilities to follow peri-ETI physiology with devices such as end-tidal CO\textsubscript{2} monitors.\textsuperscript{13,43,211}

**Physiologic stabilizing therapy other than airway management**

While airway management is perhaps the easiest prehospital procedural indicator to track, other stabilizing therapies can be just as important either singly or in combination. For example, prehospital stabilization was mentioned as a mediator of overall outcomes improvement in three European studies that reported these comparisons as a supplement to their primary endpoint (mortality).\textsuperscript{155,158} In these analyses comparing physician-staffed HEMS to physician-staffed GEMS units, the HEMS crews were significantly more likely to execute prehospital interventions such as thoracostomy or blood transfusion. Others have also remarked on the higher likelihood of appropriate fluid resuscitation or thoracostomy.\textsuperscript{153,212}

Given the importance of hemodynamics as a mediator of secondary brain injury, the TBI literature occasionally includes measures of HEMS vs. GEMS blood pressure management. Findings of improved prehospital perfusion pressure have been reported by studies that showed HEMS’ favorable TBI impact in Italy and Austria.\textsuperscript{86,212}

**Pain management**

After being neglected for too long as a priority in acute-care and prehospital medicine, the subject of analgesia now receives due attention. Commentators have written that pain care is a valid outcomes endpoint for assessing prehospital care, and that HEMS’ analgesia practice is often much more diligent than that of GEMS.\textsuperscript{35,213,214} For patients with isolated fractures, for example, reported analgesia rates range from 1.8-12.5% for GEMS while HEMS reports describe analgesia rates above 90%.\textsuperscript{50} Similar findings of better pain relief have been reported for HEMS vs. GEMS transport of cardiac patients.\textsuperscript{38}

Prehospital care experts writing about pain management acknowledge better HEMS performance with respect to analgesia, noting that as compared to GEMS crews, HEMS personnel are “a different group.”\textsuperscript{215} It is easy to argue that good pain care could be brought to bear by GEMS, but the existing evidence on what is done, is currently consistent with a HEMS pain management benefit. It seems unlikely that better analgesia practice will ever be a sole reason justifying HEMS dispatch, but it is fair to conclude that pain care constitutes an important part of a multifaceted non-mortality benefit package obtained with HEMS.

**Logistics and systems-level benefits**

**Overview**

Logistics variables such as time savings have long been employed as surrogate endpoints. For trauma, the notion of the “golden hour” underpins the logistics case for HEMS\textsuperscript{18,216} and a growing evidence base has arisen for time criticality of some non-trauma conditions.\textsuperscript{34,217-219} This subsection of the monograph considers access and time-related endpoints from HEMS outcomes studies. The endpoints to be addressed include time savings for ALS arrival to patients, streamlining of time from scenes or referring hospitals to tertiary care, and minimization of out-of-hospital (transit) time.

**HEMS as a mechanism for broad coverage with timely advanced care**

Particularly in rural or isolated areas, HEMS may represent the best means to get ALS to patients within a reasonable time frame.\textsuperscript{13,220,221-223} One prehospital expert, calculating that a single HEMS aircraft can cover roughly the same geographic area of seven GEMS ambulances, has written: “This kind of coverage, in many areas of the country, provides advanced care where it is not otherwise available.”\textsuperscript{13}

The survival benefit of HEMS-associated faster “time to treatment” (\textit{i.e.} by HEMS crews) has been noted in systems throughout the world.\textsuperscript{219,223,224} Expert reviewers including authors from the Oxford Centre of Evidence Based Medicine,
citing both HEMS evidence and also studies finding trauma mortality increasing with prehospital GEMS response delays, identify rapid access to experienced providers as a mechanism by which HEMS scene response improves injury outcomes.\textsuperscript{18,69,86,151,225} Many have found HEMS’ rapid movement of advanced care to patients improves trauma outcome even when there is no savings of overall prehospital time.\textsuperscript{87,146,197,223,226}

In some remote regions, HEMS provides the only timely access to care at the ALS level (or higher).\textsuperscript{223} Even at scenes when GEMS ALS is on site, HEMS crews’ added experience can be valuable. Many procedures executed by HEMS with demonstrated positive impact on outcome (e.g. ETI) are also within the purview of GEMS ALS providers but the HEMS crews are more likely to execute the procedures with clinical effectiveness.\textsuperscript{15,85-87,127,148,149}

In fact, GEMS ALS crews at scenes often defer procedures such as ETI to arrival of the HEMS crews who are perceived as more experienced.\textsuperscript{197} The HEMS benefit of quickly getting seasoned crews to patients is also reported as beneficial for interfacility transports, when patients are at small hospitals where non-specialist ED physicians often have less experience with high-acuity cases.\textsuperscript{13,50,58,227}

The added clinical experience usually present with HEMS crews is often complemented by a broader scope of practice as compared to GEMS. Extended practice capabilities and aggressive early stabilization (e.g. blood transfusion, antibiotics for open fractures, thoracotomy and even rare thoracotomy) have been advanced as justifications for HEMS in regions with limited GEMS capabilities.\textsuperscript{86,87,118,151,157,212,228-232}

HEMS crews’ advanced-care benefits are not restricted to executing procedures in trauma patients. Flight crews have administered critical-care therapies such as antivenom, tranexamic acid, or stroke thrombolysis\textsuperscript{233-235} HEMS transport is for many rural areas the only mechanism for interfacility movement of patients with complex medical devices such as intra-aortic balloon pumps.\textsuperscript{236}

The final aspect of HEMS’ benefit in providing ALS coverage comes into play when an area with sparse GEMS ALS coverage must transport a patient to distant tertiary care. Such transports leave the local system with inadequate ALS response capability. HEMS can either provide ALS back-up for the area that’s lost its in-transit GEMS unit or – more commonly, although less desirably – HEMS can simply execute the transport to prevent regional stripping of ALS coverage.\textsuperscript{173,237}

**Getting patients to hospitals faster: Timing endpoints and the case for time savings as a surrogate outcome**

The idea of HEMS utilization to expedite care for patients with time-critical injury and illness is not new. HEMS can potentially save time when used to take patients from scenes to tertiary care (perhaps with bypass of nearby less-capable hospitals), or from referring hospitals to higher-level centers.

When time savings involves comparing scene or interfacility transports of HEMS vs. GEMS’ execution of the same transport leg, logistics calculations are usually straightforward. When HEMS is used to bypass local facilities in favor of moving patients directly to tertiary care (e.g. trauma centers or PCI suites), there are system-level logistics benefits but time savings are not easily calculated since GEMS would have gone to a local facility.

In laying groundwork for importance of HEMS’ contributions to survival as related to time savings, it is useful to have reliable metrics allowing extrapolation of a given time savings to a given mortality improvement (i.e. “savings of x minutes translates into survival improvement of y lives”). No such linear relationship exists for the population of injured patients. However, there are data supporting extrapolation of time savings for STEMI patients undergoing transport for PCI, and for iCVA patients undergoing transport for neurointerventional procedures or thrombolytic therapy. Therefore, while there is little argument over the general desirability of time savings in trauma, the equations relating time savings to discrete outcome increments relate to STEMI and iCVA transports.

For cardiac patient transports, getting STEMI to primary PCI is the treatment of choice — improvements occur in both mortality and non-mortality outcomes such as reinfarction and stroke – if PCI can be reached within a therapeutic window.\textsuperscript{238-240} A consortium panel of USA EMS medical directors has identified as an evidence-based benchmark for quality prehospital care, the transport of STEMI patients to primary PCI within 90 minutes of EKG diagnosis.\textsuperscript{241} However, the traditional 90-minute window is not absolute. Maximal PCI benefit is achieved when door-to-balloon times fall under an hour.\textsuperscript{242} Above 90 minutes, and up to 150 minutes, each 15-minutes’ PCI time savings gains 6.3 lives per 1,000 PCI cases; there is benefit to time savings throughout a door-to-balloon PCI range of 45-225 minutes (i.e. up to 3¾ hours).\textsuperscript{243,244} Related studies that adjust for multiple factors have identified that each 30 minutes’ time savings for primary PCI is associated with improved 1-year mortality of 7.5%.\textsuperscript{90}

In iCVA, each hour of ischemic stroke results in neuronal damage approximating 3.6 years of normal aging and worsens mortality by about 16%.\textsuperscript{33,245} Considered in smaller time increments, savings of each 15 minutes in iCVA lysis
improves survival by 4%.33

**Time savings: HEMS vs. GEMS transport from scenes to tertiary centers**

The scene trauma response literature includes frequent references to the possibility of time savings as a mediator of HEMS’ outcome improvement,15,160 but there are surprisingly few trauma data directly demonstrating improved scene-case survival solely due to HEMS’ being faster.

Improved mortality associated with HEMS trauma transport is commonly attributed in part to direct transport to high-level trauma care and HEMS’ ability to extend the reach of a trauma center.18,57,99,115,141,151,179,246,247 It is not simply time savings that’s responsible for better outcomes; it’s the fact that there is bypass of hospitals lacking expertise, to get injured patients to trauma centers.177,237,246,248,264

One additional facet of scene HEMS response and time savings is the contention that, even when HEMS doesn’t result in overall prehospital time savings, the improved out-of-hospital stabilization saves time at receiving centers. Some research finds that since procedures such as IV placement and ETI have been done in the field, trauma center work-up (e.g. cranial CT imaging, urgent surgery) can proceed more quickly after patient arrival at the tertiary hospital.54,86

The system-based impact of logistics on trauma mortality has been argued in a JAMA study which found that HEMS was an important means of extending trauma center access since it represented the only mechanism by which 27% of the USA population had timely (<1 hour) Level 1 or 2 trauma center access.265 The fact that HEMS provides the only timely access to high-level trauma care is particularly noteworthy, given large-scale studies finding that trauma center care results in a distinct outcomes benefit as compared to other levels of trauma care.248,260,266

Systems-based conclusions similar to those from the JAMA trauma article just mentioned, were drawn in another study in the same journal that addressed burn patients. The paper argued that while there is no “golden hour” for burn patients, early burn center care improves outcome and HEMS is the sole mechanism by which millions in the USA can access burn centers within 2 hours of injury.267

Non-trauma cases comprise an additional facet of the evidence base assessing HEMS’ scene-run time savings benefits. The timing advantage of moving patients directly from scenes to definitive care, often bypassing local facilities with less capability, is particularly important for iCVA and STEMI. Just as the previously noted JAMA publications outlined systems-based access enabled by HEMS, there are similar findings for HEMS’ ability to provide access to advanced STEMI and iCVA care. HEMS presence is responsible for substantial increases in proportions of Americans with timely (<1 hour) access to iCVA thrombolysis (from 81% to 97%) and endovascular intervention (from 56% to 85%).268

The principle of HEMS non-trauma scene response utility is illustrated in such case reports as one from Ohio, in which HEMS responded to a rural scene where GEMS diagnosed STEMI. HEMS took the patient to a specialty-hospital PCI lab in less time than it would have taken GEMS to transport the case to a non-PCI center.218 For STEMI, as in other time-critical conditions, there is some argument for bypassing community hospitals in favor of direct transport to larger, higher-volume centers with more capabilities for primary PCI.7

Calculations pertinent to the PCI time-savings discussion come from one study that assessed interfacility HEMS transports for primary PCI that occurred from referring hospitals that had initially received those patients by GEMS. The researchers modeled the time savings that would have been accrued if, instead of transporting patients from the cardiac scenes to local non-PCI facilities, GEMS would have instead called HEMS for transport directly to PCI centers. Calculations determined that HEMS dispatch to the cardiac scenes would have saved 48 minutes from initial medical contact to PCI.269

HEMS scene response for STEMI cases going to PCI has been reported in case series. A Massachusetts study confirmed the utility of simultaneous HEMS dispatch and PCI lab notification (with bypass of the receiving center ED) to save 10-20 minutes in STEMI’s transported from the scene.55 Scene responses also comprised a part of the study set for a previously cited Danish study finding 20-30 minutes’ time savings for HEMS vs. GEMS transports of over 55 miles.270

For stroke patients, time savings is an accepted endpoint8 and HEMS has been identified as maximizing the arrival of patients to stroke centers within interventional windows. In Austria, for example, iCVA patients who were scene-transported by HEMS directly to tertiary care were more likely to arrive at stroke centers within a pre-specified 90-minute window than the other two groups assessed (those transported by GEMS to stroke centers, or transported by GEMS to community hospitals with subsequent HEMS transport to stroke centers).5 Similar extension of stroke center reach has been reported in the USA.49,188,271 Scene stroke patients were also included in a previously noted CCT CORE
multinational research group analysis finding a minimum of 15 minutes’ time savings vs. GEMS in all iCVA cases of at least 15 miles’ distance.\textsuperscript{4}

The endpoint of HEMS time savings for both trauma and non-trauma scene transports is inextricably linked to the systems question of when patients should bypass local hospitals in favor of tertiary center care. Use of HEMS as a mechanism to bypass community hospitals is not without potential objection from both the bypassed hospitals (financial reasons) and the receiving centers (patient overload). The issue is complicated because it is only partially a transport vehicle question; the bigger picture revolves around system decisions regarding which clinical services are offered at which hospitals.

*Time savings: HEMS vs. GEMS transport from referring hospitals to tertiary centers*

Interfacility timing endpoints address whether there is time gained by use of HEMS vs. GEMS in the execution of transport from referring hospitals to specialty centers. For trauma cases, HEMS’ speed in moving patients from non-trauma center hospitals to tertiary care is a long-recognized system component contributing to improved mortality.\textsuperscript{174} On a related note, loss of HEMS services increases trauma mortality in patients presenting to non-Level I centers.\textsuperscript{112,261}

For non-trauma cases, particularly STEMI and iCVA patients, HEMS has also been found to offer clinically significant time savings for interfacility transport.\textsuperscript{182,272-274} The use of air medical resources to rapidly move patients to specialized centers is logical given dicta that “time is myocardium” and “time is brain.”\textsuperscript{186,245,272,275} Substantial time savings in median transport time (from 1.7 to 1.3 hours) has also been identified in a Mayo Clinic study of HEMS transport for patients with severe sepsis.\textsuperscript{276}

Time savings with HEMS should never be assumed. Neither should it be assumed that there’s no time savings with HEMS when GEMS units are stationed at or near referring hospitals. A study from the University of Wisconsin\textsuperscript{277} reported transport times from their network of twenty referring hospitals (many with on-site GEMS and found that for all hospitals, the average HEMS total transport time was at least as good as the best ground transport time (time savings for the twenty facilities ranged from 10-45 minutes).

In time-critical STEMI cases moving from referring hospitals to PCI centers, there are data establishing the utility of HEMS in regional cardiac systems. In Cincinnati, investigators found that a series of HEMS interfacility STEMI transports rarely got patients to PCI within 90 minutes of initial presentation,\textsuperscript{278} but the door-to-balloon median (131 minutes) and interquartile range (114 to 158 minutes) fell well within the accepted window for time-savings benefit. A Cleveland Clinic report, also using a 90-minute window as an endpoint, described integration of HEMS into a system’s referral streamlining approach (e.g. HEMS autolaunch, bypass of receiving-center ED) and tripled the proportion of STEMIs reaching PCI within the cutoff.\textsuperscript{94}

The longer 120-minute PCI time window supported by the cardiology literature served as one of the endpoints in a Pennsylvania analysis. There, investigators instituted a streamlined HEMS transport program for community hospitals to get patients into receiving center PCI, and tracked the proportions of patients with time intervals from community hospital arrival to PCI wire-crossing that fell under pre-specified endpoints of 90 and 120 minutes. For both time frames, the proportions of patients meeting the timing endpoints increased significantly (under 90 minutes, from 0% to 24%; under 120 minutes, from 2% to 67%).\textsuperscript{182}

Instead of examining numbers of cases arriving at PCI within a certain time window, some investigators have simply attempted to quantify expected time savings accrued with HEMS use. In locations as disparate as Denmark and Japan, estimates for single-case STEMI time savings with HEMS vs. GEMS PCI transport fall in the range of 20-30 minutes.\textsuperscript{217,270}

As a final logistics endpoint for HEMS in PCI, there are data indicating that community hospital diagnostic or therapeutic PCI programs are often safe only when there is HEMS back-up to transport cases to tertiary care when there is need for urgent further intervention.\textsuperscript{279,280} When considering these reports of HEMS integration into a cardiac care system, the HEMS benefit is neither easy to measure nor fair to ignore.

Interfacility transport time savings with HEMS have also been reported for iCVA. An Austrian Stroke Registry analysis of likelihood of interfacility-transported stroke patients’ receiving thrombolysis (an endpoint selected to reflect timely transport) found significantly higher treatment rates in HEMS vs. GEMS cases.\textsuperscript{3} The Austrian findings were consistent with a later analysis of mostly interfacility transports from the multinational Critical Care Transport Collaborative Outcomes Research Effort (CCT CORE) group. CCT CORE found that in all cases in which HEMS was used for iCVA patients more than 15 miles’ distance from stroke centers, at least 15 minutes’ time savings was accrued; HEMS accrued a median time savings of 48 minutes.\textsuperscript{4}
Time savings: Reduced in-transit (out-of-hospital) time for interfacility transports of unstable cases

As an additional facet to the time issue, the issue of out-of-hospital time (for interfacility transports) should be considered separately from the subject of pre-trauma center time. Even if a HEMS service takes longer than local ground units to respond to a community hospital patient requiring transport to a tertiary care center, the actual time spent in patient transport is much less for HEMS patients and this parameter is sometimes critical. In one trauma study, for instance, even though the overall time characteristics of HEMS were not significantly better than ground EMS, the actual out-of-hospital time saved by HEMS use averaged 20 minutes (58 minutes for HEMS vs. 78 minutes for ground transport).216

In some patients – especially those who are in tenuous condition or who may require difficult interventions in the event of deterioration – minimization of time spent in the relatively uncontrolled out-of-hospital transport environment is a major goal. As an example, in some areas high-risk obstetric patients are often transported by air (helicopter or fixed-wing) to minimize out-of-hospital times and decrease chances of intratransport delivery. In Japan, for instance, reduction in out-of-hospital times averaged over 100 minutes for high-risk obstetric patients transported by helicopter as compared to ground; the reduction in out-of-hospital times was theorized by the authors to contribute to favorable outcomes in their transported population.52 A group from Los Angeles also found significant time savings with HEMS obstetric transports. More importantly, the Californians reported that a quarter of the obstetrics cases that were successfully air-transported to optimal delivery conditions at maternal-fetal medical centers would have stayed to deliver at referring hospitals if HEMS had been unavailable.31

**HEMS benefits in disaster and mass casualty incidents**

The helicopter offers advantages of being flexible with respect to receiving center; aircraft speed and range can bring distant hospitals into play if local facilities are overloaded. This has obvious benefit in unusual circumstances such as disasters.67,281

The versatility of rotor-wing aircraft can translate into unique utility. For example, in the case where a medical expert or team needs to be transported to the patient, the speed and logistical capabilities of the helicopter may be useful.119 This was the case in the 2005 London subway bombing mass casualty incident, during which London HEMS flew at least 25 missions involving transport of medical teams to injury scenes (Personal communication, Dr. David Baker of the UK’s Health Protection Agency, June 2007.) Others have also discussed the fact that HEMS flexibility translates into multiple potential uses during disaster and mass casualty incidents.281–285

**Conclusions regarding HEMS benefits**

HEMS potential benefits as discussed in the literature include improved survival, better functional outcomes, and favorable impacts on physiologic and procedural endpoints. There are also logistics and systems-based benefits that include some factors easily linked to patient survival (e.g. faster time to PCI) and other factors more difficult to precisely define (e.g. provision of needed back-up for rural GEMS).

The outlining of the literature’s discussion of possible HEMS benefits should not be interpreted as a blanket endorsement of all of the iterated potential advantages of air transport. The case for individual endpoints should be considered in light of the evidence most applicable to a given setting. Whether the case for a particular outcome advantage has been successfully made is a point of judgment, but understanding the nature of the endpoints and the state of current evidence should inform that judgment.

In formulating opinions regarding HEMS’ benefits, a natural next step is to ask “Is it worth the cost?” The next section introduces the complex subject of juxtaposing HEMS costs and benefits.
Section 5: HEMS cost-benefit assessment

Calculating HEMS costs and benefits in the absence of precise data

The lack of agreement as to degree, or even existence, of HEMS’ benefits is an obvious impediment to calculating air transport’s cost-benefit ratio. One review from 2010 assessed 13 HEMS cost-benefit studies and reported that in five of the analyses there was no HEMS benefit (and thus no cost-benefit); in the other eight studies HEMS cost-benefit was roughly $3000 per life-year saved for trauma and $12,000 per life-year saved for non-trauma. Perhaps equally interesting was the width of the range reported in the literature for annual HEMS costs: $116,000 to $5.6 million.\textsuperscript{286}

It’s not just the vehicle cost side of the equation that lacks clarity. Ascertaining the true, all-encompassing cost differential between air transport and alternatives is not always straightforward for a variety of reasons such as how to calculate crew costs (e.g. for HEMS crews that also work in the ED during their shifts). The inescapable conclusion is that precise cost-benefit calculations for HEMS remain elusive.

Even if there is more uncertainty than would be desirable in HEMS’ cost-benefit mathematics, the assessments must still be attempted. In the USA alone, there are hundreds of thousands of HEMS missions annually. Such a prominent part of the healthcare system cannot be free of economic scrutiny, even if the available information is not ideal.

The data that are available, strongly suggest that – at least when viewed retrospectively – HEMS is often used for cases that don’t benefit. Some authors report that in their regions, there are no HEMS-use guidelines at all.\textsuperscript{145} Others report that there’s widespread variation in compliance with dispatch guidelines even when such criteria have been promulgated by EMS regions.\textsuperscript{287} It’s thus not surprising that there are frequent reports of HEMS use for minimally acute patients for whom there was no benefit.\textsuperscript{180,288,289} Such overuse is not limited to the USA, with systems in developing regions such as Brazil reporting overuse of HEMS in the range of 1 in 5 cases being non-indicated.\textsuperscript{290}

Proponents of HEMS interpret the evidence base as demonstrating that air medical transport optimizes outcomes for both scene cases and interfacility-transported patients with a broad range of conditions. Critics tend to disagree with HEMS proponents on the question of degree of outcomes benefit, but even the most ardent HEMS critics usually concede HEMS appears useful in occasional cases. Thus, the true debate isn’t over the question of whether HEMS has any associated benefit; the disagreement is over the ratio of costs to benefits accrued. This section assesses the existing evidence weighing HEMS’ costs against benefits.

Definitions and principles underpinning HEMS economics studies

Placing a dollar value on morbidity and survival improvement is complicated, involving mathematics, assumptions, and even nomenclature that can be daunting at first sight. Those who have delved into the detailed economic analysis required for truly rigorous cost-benefit calculations have noted difficulties in such maneuvers such as assigning value to human life.\textsuperscript{291} This section’s discussion is meant to be no more than a superficial introduction to the concepts and their application in HEMS.

The definitions of economic study endpoints can be confusing. This monograph’s author – who claims no expertise in this arena – learned in graduate school that cost-benefit analysis measures outcomes in dollars (or some other currency units), cost-effectiveness analysis uses a non-dollar outcome (e.g. lives saved).

The cost-effectiveness study is sometimes referred to as the “real-world” economics analysis. After one performs a cost-benefit calculation, the next step is to compare the relative cost-effectiveness of a number of options, to determine which accrues the most benefit for a given amount of cost. This is an important step in the HEMS topic, because some of the cases in which HEMS may have the most benefit (e.g. isolated geographical conditions) are characterized by both high cost for HEMS and high differential cost-effectiveness if HEMS is compared to alternative transport modalities. Patients at scenes or referring hospitals, who will undergo attended transport to a hospital, must have some form of EMS. Therefore, cost-benefit analysis of HEMS should not be considered in a vacuum; instead, real-world calculations should consider the differential costs of HEMS vs. non-HEMS alternatives (e.g. GEMS, boat, snowmobile-and-sled).

In cost-effectiveness analyses, a final option against which HEMS transport costs and benefits should be weighed is the option of no transport at all. This option would have been selected in a quarter of obstetrics cases in one Los
Angeles series, in which HEMS unavailability would have resulted in delivery of high-risk cases at community hospitals without advanced maternal-fetal medicine capabilities. The adjudication of costs and benefits of HEMS in such cases should include the monetary expenses as well as medical-outcome “costs” of patients for whom the only non-HEMS option was the no-transport option.

A third metric in health economics is the Quality-adjusted life-year (QALY), which is assessed in cost-utility studies. Use of QALYs is intended to adjust for various levels of functional survival. Death is given a value of 0, and perfect health a value of 1, with varying degrees of health assigned intermediate values. It can be tricky to assign a level of 0 to 1 to a given quality of life – some investigators use negative numbers for some conditions – but the QALY unit remains a broadly accepted metric.

Although these terms and approaches are often found in textbooks, many HEMS studies don’t rigidly adhere to the strict definitions. In general, this monograph will trade precision for consistency, using the term “cost-benefit” in non-technical application. However, readers of the economic outcomes literature are cautioned to carefully consider a given study’s specific outcome metric in the framing of that study’s results.

Complexity increases when one attempts to account for the bigger picture of costs and benefits. Saving a life doesn’t accrue any benefits if the patient who has been saved is in a vegetative state. Also, from a utilitarian perspective it may be more “beneficial” (in QALYs) to save a 9-year-old vs. saving a 90-year-old.

Ever the best available cost-effectiveness studies for HEMS are flawed in a number of ways that result in imprecision that is likely to substantially underestimate HEMS benefit. These shortcomings, acknowledged by study authors themselves, are related to assumptions and excluded information regarding both HEMS’ relative costs and air transport benefits. For example, one of the most rigorous health-economics studies of HEMS trauma scene response failed to consider four major benefits – all previously addressed in this monograph – that could be accrued with HEMS. As noted by cost-benefit study authors themselves, calculations did not address the following HEMS-related benefits: 1) morbidity and other non-mortality clinical benefits, 2) provision of ALS-level coverage in areas that would otherwise lack such coverage, 3) prevention of regional loss of GEMS ALS coverage during long transports that would have been executed by GEMS if HEMS were not used, and 4) direct transport of scene trauma patients to trauma centers rather than having GEMS take those patients to nearby non-specialty centers. This key information is largely absent in many – even the best – of the HEMS cost-benefit studies.

Another consideration when assessing vehicle costs of HEMS is the concept that some regions are forced by geography (e.g., rural areas, service regions with terrain such as mountains or islands) to procure and operate air transport services. In these cases, justification of the system’s resource commitment on HEMS is based on system issues rather than individual patient transports. When this is the case, there may be less incremental cost (i.e. more favorable cost-benefit) for a given HEMS deployment. Once the HEMS service is bought and paid-for, it may be fair to judge that less mission-specific benefit is necessary to justify dispatch.

Capital equipment is not the only cost arena that can be tricky in cost-benefit calculations. Since different HEMS programs operate on different staffing and operational models, personnel costs may differ. For instance, in some cases the HEMS crew salaries are “covered” under a hospital’s cost center, since the HEMS crew serves as extra help in the ED or elsewhere (e.g. as the hospital’s “IV team” for difficult-access patients). How should HEMS crew costs be calculated in these situations? This discussion makes no pretense at having the answers to either equipment or personnel cost calculation questions, but it should be obvious that the issues are sufficiently complex that one cannot simply say “helicopters are far more expensive than ground ambulances.”

The “acceptable” threshold for healthcare interventions is not universally agreed. Health policy and medical experts writing in the field tend to place it between $35,000 and $100,000.

Evidence assessing overall (trauma and non-trauma) HEMS program cost-benefit

This subsection examines conclusions of authors reporting HEMS cost-benefit on a program-wide level (i.e. all patients of all diagnoses undergoing HEMS transport). The evidence base is not rich, but there are some pertinent studies. In this subsection and those that follow, monetary units have been converted to $US.

One of the earliest detailed assessments of HEMS’ overall costs and benefits was a 1996 U.K. report of virtually no HEMS benefit (and obviously unacceptable cost-benefit). Interestingly, seven years later some of the same British authors reported opposite findings. Their 2003 governmental audit placed HEMS’ cost-utility in the range of $10,000-$30,000 per QALY, noting this range was similar to that reported elsewhere in Europe and that it was well within the
U.K.’s “acceptance threshold” of $35,000/QALY.\textsuperscript{296}

In another government report, an independent analysis of HEMS’ cost and benefit data conducted at the Canadian Institute of Health Economics concluded that “air medical services appear to be expensive on a single-case basis but not at a system level.”\textsuperscript{1} Additional data supporting cost-benefit of air medical services comes from economics studies from South Africa.\textsuperscript{298,299} Overarching reviews conclude that the majority of analyses find HEMS to be cost-beneficial.\textsuperscript{300}

Scandinavia provides some of the most rigorous investigations of HEMS cost-benefit. A Norwegian study assessing the entire spectrum of HEMS transports concluded: “The analysis indicates that the benefits of ambulance missions flown by helicopters exceeds the costs by a factor of almost six.”\textsuperscript{291} The Norway estimate (a cost-benefit ratio of 1:5.87) indicates that the HEMS operations quite easily paid for themselves, and in fact reaped a substantial return on investment. Convinced by the health economics data, Norway set (and achieved) a national goal of having 90% of the population reachable by HEMS within 45 minutes.\textsuperscript{301}

Norway’s neighbors have also contributed to the HEMS cost-benefit knowledge base. Calculations for a rural HEMS service providing scene responses in Finland yielded an estimate of $30,000 per beneficial mission.\textsuperscript{723} A Swedish HEMS analysis assessing an interfacility HEMS unit determined that while fixed-wing vehicles were most cost-effective once distances exceeded 300 km (186 miles), at shorter transports HEMS was preferred from an overall cost-benefit perspective.\textsuperscript{302} A Danish group failed to find quality-of-life benefits from HEMS iCVA transport, but concluded that their broad confidence intervals indicated low power to detect a HEMS benefit.\textsuperscript{303}

The USA provides data addressing cost-effectiveness of HEMS vs. similarly expert GEMS crews spread over a New England region covered by one HEMS unit. The authors concluded that even if one could fiat HEMS-crews’ experience and expertise across a large group of widely dispersed GEMS crews, cost-benefit calculations still favored HEMS.\textsuperscript{11,304}

A decade after the New England report, South Africans confirmed the difficulties – before any monetary considerations entered the picture – of providing high-level GEMS crews in a broad region. The South Africans concluded in favor of HEMS’ cost-benefit even with an assumption that HEMS-level GEMS crews could be deployed: as compared to a single GEMS unit, a single HEMS unit cost 3.2x more but covered 3.3x more area.\textsuperscript{298,299}

Perhaps the most important point to consider in these overarching cost-benefit assessments, is that they are executed using sets of actual HEMS transports that occur in a world of acknowledged triage imprecision. As will be noted subsequently in this monograph, triage is an imperfect science so it’s important to take into account the lack of ideal specificity seen with current HEMS dispatch criteria. Any refinements in triage and associated improvements in HEMS use appropriateness, can only improve air transport’s cost-benefit.

**Evidence assessing cost-benefit of HEMS vs. GEMS for trauma transports**

The weight of HEMS outcomes data addresses transported of the injured, so it is not surprising that the weight of diagnosis-specific economic evidence evaluates HEMS use for trauma. Data from around the world support a contention that HEMS has favorable cost-benefit for response to injury scenes.\textsuperscript{154,197,305,306} This may be simply because patients are transported directly to scenes to trauma centers where more expert care translates into improved outcomes (and thus more favorable HEMS cost-benefit).\textsuperscript{177,260}

It’s possible that some HEMS scene response cost-benefit arises from cost savings via eliminating the community hospital stop in a patient’s pathway from injury scene to trauma center. It has been long-known that there are substantial costs incurred transporting patients to a lower-level hospital before secondary transport to a trauma center. Studies from nearly two decades ago found that the extra hospital stop adds at least $700 to per-patient transport expenditure.\textsuperscript{305} Similar preventable costs occur due to repetition of laboratory and radiology evaluation at referring and receiving hospitals.\textsuperscript{307} Expenses have doubtless increased over the years, so monetary costs of an intermediate stop at community hospitals should be considered important.

Dutch traumatologists and health-economists have assessed HEMS’ cost-effectiveness in their system of scene response. The calculated cost/QALY range for HEMS supported the authors’ conclusion that air medical transport was at least as cost-effective as well-accepted procedures such as heart, lung, or liver transplants (which had reported cost/QALY of $50,000-$100,000).\textsuperscript{197}

In New South Wales, Australians found that HEMS scene response was associated with cost per life-year saved of $72,000 for all trauma patients. The cost per life-year saved was an even more favorable $37,000 for patients with ISS exceeding 12, and $36,000 was the cost per life-year saved for TBI cases.\textsuperscript{306}

The Australians’ focus on TBI cases was echoed by findings in the USA, where it was noted that HEMS’ favorable
impact on TBI would have important ramifications for major cost-savings in arenas such as long-term rehabilitation.\textsuperscript{14}

Non-mortality benefits to HEMS trauma scene response have been judged worthy of consideration.\textsuperscript{154,196} There is occasional evidence addressing economic endpoints such as days off of work; HEMS has been determined in one study to reduce government-subsidized time off of work.\textsuperscript{308} At this point, the evidence is sufficient only to conclude that limitation of cost-benefit analysis to mortality endpoints likely underestimates HEMS’ favorability.\textsuperscript{154}

One factor that can influence cost-benefit analysis is the practice of autolaunch. While the term can mean different triggers for HEMS in different areas, the practice of helicopter dispatch based on minimal criteria has potential both for increased benefit and increased cost. On the benefit side of the equation, autolaunch can reduce by nearly 75%, the transport radius at which HEMS becomes faster than GEMS.\textsuperscript{309} The benefits come at a significant cost, though. In Minnesota, where lay passersby can activate HEMS (\textit{i.e.} before law enforcement or first-responder arrival), autolaunch was judged cost-beneficial but the mission completion rate was just 21\%.\textsuperscript{13}

It is noteworthy that some of the same investigators who have identified major need for improvement in triage, have also found (in the same population in whom suboptimal triage was being applied) that HEMS was indeed cost-effective.\textsuperscript{197} Health-economics analysts comprise an important part of the chorus asking for better triage.\textsuperscript{28} However, rigorous assessments of cost-benefit in the current era of flawed triage have found scene trauma HEMS to be cost-effective (using the target of $100,000 per life-year saved) at a \(W\) threshold of 1.3, which is quite consistent with the outcomes benefits suggested by the preponderance of both the scene and interfacility HEMS trauma transport literature.\textsuperscript{28,48,131}

Evidence assessing cost-benefit of HEMS vs. GEMS for non-trauma transports

Cost-benefit for non-trauma transports is limited by the lack of precise point estimates for benefits. Some of the non-trauma literature is suggestive of favorable cost-benefit, via time savings or other mechanisms, but the measures are either indirect or difficult to measure. The high-risk obstetrics transport literature is emblematic. In considering outcomes of both mother and newborn, high-risk deliveries best occur at maternal-fetal medicine centers. Currently available evidence suggests HEMS use occasionally enables these deliveries to occur at tertiary care centers instead of community hospitals; this is clearly cost-beneficial but not in an easily quantifiable fashion.\textsuperscript{31}

Episodic examples of non-trauma cost-benefit aside, the two diagnostic groups with the most robust evidence basis for HEMS cost-benefit calculations are STEMIls (transported for PCI) and iCVAs (transported for thrombolysis or neuro-interventional therapy). For each of these groups there is time-windowed therapy and broadly accepted linkage between faster access to definitive care and improved outcomes.

One method to calculate cost-benefit in STEMI or iCVA HEMS transports is to count those HEMS cases receiving time-windowed therapy, that would not have been eligible for such therapy had they gone by GEMS.\textsuperscript{34,55,292} This has been executed for both STEMI and iCVA populations. One multicenter HEMS STEMI investigation, CCT CORE’s HEARTS study, reported a NNT of 3: for every 3 STEMIls transported by HEMS vs. GEMS, one additional patient underwent PCI within a predefined endpoint of 90 minutes (study submitted for publication as of 2017). Another analysis of over a hundred STEMI cases evacuated off of a Baltic island reported what was essentially a NNT of 1; HEMS was the sole transport modality allowing achievement of within-window PCI.\textsuperscript{183}

Obviously, cost-benefit calculations related to logistics are dependent on situational specifics. Examining the broader picture of transports in Norway, one group concluded that HEMS incorporation into a regional STEMI system extended PCI cost-benefit over a much broader geographic area.\textsuperscript{310} Similar findings have been reported in the USA, where health economists determined that centralizing PCI and establishing well-developed transport networks (including HEMS) was more cost-effective than spreading PCI capabilities across multiple smaller hospitals.\textsuperscript{236}

Conclusions regarding HEMS cost-benefit

Readers should keep in mind that in the absence of benefit, cost-benefit will not be present. Investigators who find no HEMS benefit will not pursue cost-benefit calculations. This truism is doubtless partially responsible for the one-sided nature of the HEMS cost-benefit literature.

Regardless of which direction the existing evidence points with respect to HEMS cost-benefit, the subject is far more complex than its presentation here. The data presented in this section are intended only to familiarize the reader with basic concepts, and to provide tools that might be useful in reading cost-benefit analyses.
It is hoped that the data presented will allow the reader to view the recurring HEMS-study opening statement – “helicopter transport is expensive” – from a rational standpoint. HEMS is undoubtedly a costly and resource-intensive service. However, the question as to whether HEMS is “too expensive” requires judicious weighing of costs and benefits of HEMS as compared to alternatives of either GEMS or no transport at all. Common sense and available data support the conclusion that the best cost-benefit for HEMS will be achieved by a rational, evidence-driven transport triage process including both HEMS and GEMS.\textsuperscript{311}
Definitions and principles underpinning HEMS utilization appropriateness

It’s often written that HEMS should be used only when appropriate. While correct, this truism doesn’t provide much practical guidance for healthcare providers facing a right-now decision as to transport mode for their patient.

Unfortunately, there are few specific, practical, validated criteria for HEMS vs. GEMS transport decision-making. This fact is nearly always elided in the seemingly endless stream of retrospective “HEMS appropriateness” studies using a posteriori methodology to classify many air-transported patients as GEMS-eligible. Such reviews are accurate, but these after-the-fact HEMS appropriateness categorizations do little to advance triage science.

This section considers the inextricably related topics of triage and HEMS utilization appropriateness. First, a few definitions should be clarified as to their use in this monograph. Some terms as applied to HEMS triage have similar meanings, and this means they are occasionally used interchangeably in a fashion that can be confusing.

- **HEMS triage** refers to decision-making regarding choice of transport modality. In this monograph, the term applies to the vehicle decision-making that occurs either at a scene or at a referring hospital.
- **Overtriage** occurs when the use of HEMS for a patient is associated with no outcomes benefit (to either the patient or the system). Overtriage is inherent in HEMS dispatch, just as it is inherent in execution of many medical decisions (e.g. sometimes an appropriately ordered CT scan comes back normal).
- **Overutilization** occurs when there is overtriage that is avoidable. No triage guidelines are perfect, so cases overtriaged to HEMS could still be appropriate utilization; this is the case if HEMS triage is defensible in light of applicable dispatch guidelines and information that was contemporaneously available to triagers.

**Trauma triage and HEMS appropriateness for injured patients**

**Framing the issue**

Determination as to which injured patients need HEMS for scene missions is a theoretically straightforward two-step process. First, decide if the patient needs a trauma center. Then, after deciding the patient needs a trauma center, decide if the case warrants HEMS response for some combination of flight crew skills and logistics.

Unfortunately, the conceptual simplicity of HEMS triage does not translate to practical simplicity. On-the-spot decisions made at trauma scenes can be rendered difficult by time pressures and myriad unknowns. Understandable bias in favor of erring on the side of overtriage must be balanced against using HEMS for trivially injured patients who walk out of the hospital within hours of arrival.

This monograph does not intend to delve too deeply into the complex and sometimes frustrating science of trauma triage. However, since general trauma triage is inextricable from HEMS trauma triage, some attention must be given the triage issue. It is not rational to expect HEMS triage to be any more precise than triage to trauma centers: if it’s not known with any precision whether a patient needs to go to a trauma center, it certainly cannot be known with precision whether that patient needs HEMS.

**Overtriage to trauma centers: performance of currently used criteria**

There is broad recognition that the various currently used triage approaches are in need of improvement.\(^1\,^6\,^13\,^2\,^3\,^1\) A relevant consensus opinion from the organizers of the CDC’s Field Triage meetings was that “current triage criteria are wanting in terms of sensitivity and specificity of identifying severely injured patients, or more accurately stated, patients who would most benefit from Level I trauma center care.”\(^2\)\(^6\) Years after the CDC opinion was written, a *JAMA* report of HEMS mortality benefit in its study population of cases with major trauma (ISS >15) again highlighted the ongoing triage problem of identifying those major-trauma patients: “To date, the development and use of effective pre-hospital triage tools that can identify adults with a high ISS have remained elusive.”\(^1\)\(^5\)\(^4\)

There is no known combination of anatomic, physiologic, and mechanism criteria that reliably identifies patients needing high-level care while eliminating overtriage. It is well known that limiting triage decisions to anatomic and

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Section 6: Optimizing HEMS utilization

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physiologic variables results in dangerous and inappropriate levels of undertriage, rendering prehospital provider judgment (including assessment of injury mechanism) a necessary criterion.252,259,261,314-320 On the other hand, it is just as clear that incorporation of these additional triage criteria inevitably leads to more cases of overtriage.321,322

The difficulties with triage mean there must be room for situational judgment with trauma scene triage as well as secondary triage at community hospitals (where physicians are determining which cases need to go to trauma centers).252,259,261 The goal for trauma center triage has long been based on an American College of Surgeons (ACS) statement that “an undertriage rate of 5-10% is considered unavoidable and is associated with an overtriage rate of 30-50%.”323

Phrased in a different fashion, the ACS’ benchmark for undertriage requires trauma center triage criteria sensitivity of 90-95%. Investigators around the world have found that to achieve such sensitivity, overtriage often exceeds the ACS’ estimate of 30-50%.259,314,324 An Irish group, for instance, concluded that appropriate HEMS scene triage in their system was associated with an unavoidable (and acceptable) 25% rate of discharge from the receiving ED.325 Studies from the USA are also illustrative.

In one USA cohort, limitation of trauma center triage to anatomic and physiologic criteria yielded a sensitivity (87%) that didn’t quite reach the ACS goal, and yet still resulted in an 80% overtriage rate.326 Similar results were found in a 2013 analysis of multiple different triage models’ performance in the western USA. In order to reach the prespecified goal of 95% sensitivity, even the best model had poor specificity (81% overtriage) with triage precision being even worse for geriatric trauma.324 The report showed that frustratingly little progress had been made in the decades since demonstration of the fact that following a strict set of ACS triage criteria could achieve excellent 97% sensitivity, but at a cost of an 82% overtriage rate.327

Some of the USA’s most rigorous trauma center triage analyses are based on data from New York State’s population-based trauma registry. Heart rate (HR) is but one of many interesting and instructional points made by those registry data. HR is an obviously non-specific measure, but it was included in the state’s final triage model since abnormal HR (<50 or >120) was the only criterion present for 26% of cases requiring major operative intervention.259

In addition to its findings that need to optimize sensitivity dictated a need for trauma center triage rules to include non-specific criteria such as HR, the New York data also addressed the question: Can trauma center triage be based solely on anatomic and physiologic criteria? The answer was “no”, since restricting trauma center destination decisions to these factors failed to identify 43% of cases needing urgent operation.259

Overall analysis of the New York data revealed that, to improve trauma triage sensitivity from 85% to 95%, each additional “true-positive” case identified by loosening triage criteria would come at a cost of approximately 100 unnecessary (overtriaged) patients.259 Not surprisingly, experts from New York concluded that the suboptimal performance of triage criteria translated into a need to accept overtriage.259

If overtriage is unavoidable, what level of overtriage is acceptable? As previously noted, the ACS states 30-50% overtriage is unavoidably associated with maintaining desired triage sensitivity.323 The high end of the ACS range (i.e. 50%) is commonly cited, but there is no universally agreed benchmark and many experts report overtriage rates can range to 90%.99,117,314,328

Triage of trauma cases to HEMS transport: Challenges and evidence

If half of the patients directed to trauma centers are overtriaged, it is hardly surprising that many trauma cases airlifted to trauma centers are overtriaged. Of course, most patients who need trauma center care don’t need a helicopter to get there and there’s no controversy around the fact that currently used HEMS triage criteria often dispatch aircraft for cases that don’t benefit from HEMS. The difficulty, of course, is the application of available evidence to support specific changes to triage guidelines so HEMS triage criteria maintain sensitivity without undue overtriage.321 Thoughtful critics of HEMS triage have written that “The decision to use a helicopter is not straightforward, and a number of important geographical, physiological, and pathological factors need to be considered.”329

Tackling the question of whether HEMS triage was indicated requires an answer to the question: “Did HEMS benefit the patient?” If triage appropriateness is defined as being present when patients had high likelihood of receiving benefit from HEMS deployment, then assigning appropriateness judgments relies on some assessment of the probability of HEMS bringing benefit in a given case. (As mentioned earlier, there are cases in which system issues rather than patient-centered benefits can justify HEMS use; such system benefits are addressed elsewhere in this monograph.) Adjudication as to whether patients benefited from HEMS can be individualized by transport, by asking questions such as “did HEMS crews provide life-saving therapy?” or “did the patient need urgent operative intervention?” These
questions are straightforward sometimes, but not always. Who decides what therapy was life-saving, or what operations were urgent? Is every ETI life-saving? Is every operation within 24 hours urgent enough to warrant HEMS?

The inherent subjectivity in assessing case-by-case HEMS transports for triage appropriateness has led many investigators to use ISS cutoffs to define appropriate HEMS use. While ISS has disadvantages, the scores are assigned in objective fashion (i.e. with no reason for bias towards higher or lower scoring based on transport mode). Furthermore, the HEMS outcomes evidence base itself tends to use ISS cutoffs to define groups benefiting from HEMS transport. The use of ISS to define cases for which HEMS is indicated is therefore objective, common, and as much evidence-based as any other method for adjudicating HEMS appropriateness.

ISS use for defining HEMS triage appropriateness does have a few problems. The most important is that ISS can only be used for *post hoc* appropriateness assignments. The challenge of defining triage criteria that will predict high ISS remains. The second problem with using ISS cutoffs to define HEMS appropriateness is the determination of which cutoff to use; the HEMS outcomes evidence base supports different cutoffs.

The large-scale *JAMA* investigation and other studies such as the previously referenced Australian study used an ISS cutoff of 15 to define “major” injury. Many others also use the ISS >15 cutoff; an example study from 2014 reports a Dutch finding of 5.3 lives saved per 100 dispatches with the denominator consisting of cases with ISS >15. However, there are many data demonstrating that HEMS improves outcomes in a group constituted by patients with lower ISS cutoffs. Some representative evidence includes the following:

- A Canadian population-based study demonstrated definitive improvement (W 8.8 air versus ground) with HEMS use for patients with ISS scores ≥12.
- The same cutoff of ISS ≥12 was used by another Canadian group in 2016, in a study finding HEMS-associated W advantage of 6.6.
- A cutoff one point higher (ISS >12) than the Canadians used, was demonstrated to define HEMS cost-effectiveness in a 2012 Australian study.
- Germans have used large trauma registry databases to lower the ISS cutoff defining HEMS benefit even lower, to ≥9. After an initial (2013) report in which HEMS was found to bring a 25% mortality reduction for cases with ISS ≥9, the Germans followed up with a larger study of over 50,000 cases (a third of which came by HEMS) confirming HEMS improved survival for the set of injured cases with ISS ≥9. In fact, a 2016 German analysis found that HEMS was most beneficial relative to ground transport, for the ISS group 9-15 (OR for survival, 0.66).

In light of the above findings, setting an ISS >15 cutoff to define HEMS will fail to identify all patients for whom the available evidence firmly suggests outcomes improvement and cost-effective HEMS use. Even if the ISS is chosen as an objective well-proven measure of injury acuity to define HEMS triage appropriateness, there remains the question as to where the cutoff should be set.

*Triage of trauma cases to HEMS transport: Current status and implementable goals*

The difficulty of establishing ideal triage criteria does not obviate the need for regional trauma systems to generate guidelines both for determining destination and transport mode. Having any set of rationally designed criteria is preferable to having no guidelines at all, since the latter situation invariably results in substantial HEMS overutilization.

For regions aiming to optimize use of trauma center and HEMS resources, the first step is to establish triage criteria addressing hospital destination and transport mode. While the current science limitations mean no triage criteria are ideal, recent years have seen publications that can be used as bases for a region’s implementation of improved HEMS trauma triage. The NAEMSP HEMS dispatch criteria (see later section in this monograph) provide a good starting point for regional HEMS-use guidelines.

One little-discussed aspect of HEMS triage imprecision is undertriage. Undertriage is a well-recognized cause of increased morbidity and mortality in the trauma population. In fact, in developing trauma systems the appropriate concern for overtriage is balanced by data that have prompted major concern for HEMS undertriage (in South Africa, for instance). Even in well-developed trauma systems (e.g. Germany), investigators confirming HEMS’ survival impact have expressed concern about underutilization of the resource.

HEMS trauma undertriage is also an issue in the USA. In an era of increasing non-availability of surgical subspecialty
coverage for trauma, HEMS may play an increasing role in quickly evacuating patient (from scenes or community hospitals) where they simply cannot get the interventions they need.\textsuperscript{252,255,261} Prominent trauma surgeons have contended that it is undertriage to transport a patient with potential need for specific surgical subspecialty care (e.g. brain injuries) to any hospital, regardless of trauma center level, that does not have access to an on-call subspecialist.\textsuperscript{255} These considerations are just some of the region-specific parameters than should be incorporated into a trauma system’s HEMS triage criteria.

If design of HEMS trauma triage guidelines is one implementable goal, another such goal is the assurance that region-specific guidelines are actually followed. Whatever difficulties lie in design of HEMS trauma triage criteria, once those criteria have been designed and agreed within a region, they should be followed. Unfortunately, within trauma systems around the world there is broad variability in compliance with region-specific HEMS dispatch guidelines.\textsuperscript{287,332} Fortunately, efforts such as work in North Carolina have demonstrated that HEMS overuse can be reduced by institution of active reviews and plans to improve compliance with air transport use guidelines.\textsuperscript{333}

HEMS triage imprecision is certainly not limited to prehospital providers: physicians at referring hospitals are not consistently able to execute better triage than EMS crews at trauma scenes. Recent assessment of over 10,000 injured patients undergoing initial evaluation at 43 referring hospitals in Oregon found that even after adjusting for patient and logistics characteristics, there was substantial heterogeneity between different institutions’ transfer practices.\textsuperscript{334} Analysis of particular diagnoses (e.g. spinal trauma) provides further evidence that secondary transfer of these cases is often inappropriate.\textsuperscript{335} The message is not that referring physicians are particularly poor at triage. Rather, the point is that triage is difficult and imprecise both at the trauma scene and the community hospital – physicians are not significantly better triagers than prehospital providers.\textsuperscript{261,334,336,337}

The HEMS trauma triage discussion can conclude on a positive note. In addition to the constant evolution of the science of trauma triage, there are additional grounds for optimism in the fact that existing literature frequently demonstrates HEMS outcomes improvement with current (imprecisely triaged) helicopter deployment.

One point for optimism lies in the fact that often, it is the same investigators who demonstrate both a need for triage improvement and overall HEMS-associated mortality benefit.\textsuperscript{175,176,179,197,287} On a nationwide scale, a national trauma registry analysis of over a quarter of a million trauma transports – triaged in imperfect systems around the USA – clearly demonstrated HEMS patients’ higher acuity as well as a 22\% mortality reduction with HEMS scene trauma response.\textsuperscript{151} This large-scale study reported other findings of note with regard to HEMS cases across the country, that should be interpreted as a reason for optimism in light of the well-known problem of imprecise triage:

- Rate of discharge within 24 hours was much lower (<15\%) than previously speculated.
- Almost half of cases required ICU admission; 20\% were on ventilators, for an average of seven days.
- Nearly a fifth of patients underwent urgent operative intervention.
- Average ISS was at least 15 for cases with pre-trauma center transport time under 2 hours.
- The authors concluded that “On a national level, patients being selected for HEMS are appropriately sicker and are more likely to use trauma center resources than those transported by ground ambulance.”\textsuperscript{151}

The above points include an important logistics finding, that when patients were grouped by prehospital time, the average ISS of HEMS transports did not fall below 15 until total prehospital times exceeded 2 hours. The time-distance calculations that inform HEMS triage comprise an important part of transport mode decision-making; approaches to these calculations are addressed in a later section of this monograph.

One reasonable conclusion from the evidence outlined in this subsection is that trauma triage needs improvement and that until such improvement occurs, HEMS triage will continue to be suboptimally specific. The lack of perfection in triage criteria, while no excuse for cases of obvious HEMS overuse, should be remembered by those quick to criticize aircraft dispatch by looking at cases after the fact.

**Triage of HEMS for non-trauma missions**

Apart from its use for geographical or systems-related indications (e.g. remote-access ALS coverage), HEMS triage for non-trauma diagnoses can be even more case-specific than helicopter dispatch for trauma. Whereas the aircraft may be useful for diagnoses such as aortic aneurysm or high-risk obstetrics, it’s certainly not necessary to activate HEMS for all cases of aortic disease or pregnancy. Even for iCVA and STEMI, the two non-trauma diagnoses for which
there is clear potential for time-savings benefit, HEMS is only appropriate when it will save significant time in a patient receiving windowed therapy. Non-trauma triage decisions in STEMI and iCVA cases should thus be guided by the discussion from the previous section addressing HEMS’ influence on time-related endpoints and those outcomes (e.g., savings of at least 15 minutes is arguably a solid reason to triage to HEMS for patients being transported for primary PCI or time-windowed iCVA care).

As much or more so than is the case for trauma cases, in non-trauma populations there is need to accept some degree of HEMS overtriage due to the relative paucity of high-quality guiding evidence. As of this time, the best available consideration in guiding non-trauma patient triage to HEMS is that provided by groups such as the NAEMSP (see next section); still, these guidelines should not be universally implemented but should instead serve as the starting point for HEMS non-trauma triage criteria.

Every patient scenario is different, but HEMS use for many non-trauma cases is based largely on the concept of time savings. This monograph has already outlined the evidence basis for at least two large non-trauma patient groups (iCVA and STEMI) demonstrating morbidity and mortality benefits from reducing time to definitive care by as little as 15 minutes. If it is true that time savings are associated with improved outcomes in some patients, the next step in triage to HEMS is to determine which situational logistics are predictive of a clinically significant time savings. The next section addresses logistics considerations that can inform decisions about HEMS triage for non-trauma (as well as trauma).

**HEMS triage: Logistics considerations**

Although occasionally HEMS use is driven by lack of GEMS access (e.g. islands, mountains), logistics in HEMS triage is usually approached in terms of mileage or time cutoffs. Using these types of cutoffs can potentially objectify HEMS triage, restricting aircraft dispatch to cases with favorable logistics. This section of the monograph outlines evidence on various time and distance cutoffs.

An important caveat to reading the HEMS logistics literature is that the usual endpoint, arrival at receiving hospital, presumes that no HEMS benefits occur from earlier arrival of skilled flight crews. This may or may not be the case for non-trauma patients (e.g. STEMs, iCVAs) with primarily time-critical transport needs (although there is evidence that points to scene-time prolongation as being associated with improved physiology even in the non-injured). For trauma, however, the restriction of HEMS triage to logistics considerations ignores decades of evidence showing HEMS outcome benefit even in the absence of time-savings benefit. With this limitation in mind, it is still useful to consider logistics that can inform HEMS triage.

**Mileage cutoffs for HEMS triage**

There are those who posit that specific distance considerations should be the major trigger for HEMS dispatch. This subsection considers mileage-based triggers for HEMS use.

Much of this subject area’s evidence base uses an endpoint of total elapsed time from transport initiation to tertiary facility arrival. Studies set the receiving hospital as the center of a circle and calculate the radius at which HEMS becomes faster than GEMS in getting patients to the circle’s center. Representative findings from these studies, which include both scene and interfacility mission types, include the following:

- In a largely rural setting of upstate New York, GIS software was used to generate a radius from a trauma center at which HEMS use reduced pre-trauma center times. Helicopter transport was found to speed pre-hospital time (by a mean of 13 minutes) at distances of 6-15 miles from the trauma center.
- In a Southern California trauma system employing autolaunch, HEMS becomes faster than GEMS at 10 miles’ distance from the trauma center. (With standard “no-autolaunch” dispatch, HEMS wasn’t faster at getting patients to trauma centers until transport distance reached 45 miles.)
- A population-based study of trauma cases in Pennsylvania found that mortality improvement from HEMS’ proximity to trauma scenes became statistically significant once distances from trauma centers reached 11 miles.
- A 2016 analysis of the USA’s NTDB finds that HEMS is associated with a significant survival increase when HEMS transport distances reach 14.3 miles (interestingly, the highest percentage of survival benefit was...
found for the close-in transports and HEMS benefit disappeared altogether when transport distance exceeded 71 miles.\textsuperscript{9}

- A multinational six-center analysis found clinically significant time savings for 100\% of HEMS iCVA transports in its study group comprising cases transported at least 15 miles.\textsuperscript{4}
- Neurosurgical patients in Korea were found to arrive at the hospital faster by HEMS at transport distances exceeding 31 miles (50 km).\textsuperscript{341}
- In Australia, it was determined HEMS saved time to trauma centers when transport distances exceeded 62 miles (100 km).\textsuperscript{342}
- At the high end of the mileage spectrum, a Swedish group attempted to determine when transport distances were so far that fixed-wing was preferable to HEMS. Their study concluded that airplanes became more cost-effective at transport distances exceeding 186 miles (300 km).\textsuperscript{302}
- Also at the higher end of the distance range, investigators in rural states have pointed out that for some long-distance flights (the discussion context was rural transports with an average distance of nearly 100 miles) air transport is a practical necessity for maintaining local GEMS coverage.\textsuperscript{342}

Given the above, it is clear that some region-specific mapping and planning will be in order for those trying to determine guiding mileages for their own area’s vehicle triage. Furthermore, planners should be mindful that endpoint selection (\textit{i.e.} flight crew arrival at patients or patient arrival at tertiary care) can greatly influence determinations of distances at which HEMS may be indicated.

One approach that may be useful in various trauma systems is that taken in Pennsylvania, where fatal motor vehicle crash sites were mapped and HEMS locations plotted to optimize system utilization. The Pennsylvanians calculated that logistics-guided HEMS placement at two remote sites of frequent trauma would achieve a relative mortality reduction of 12.3\%.\textsuperscript{343}

As a final consideration for distance as a driver for HEMS placement, planners should keep in mind that in many cases the helicopter is not responding from the receiving hospital but from a separate location. When remote aircraft placement is the case, systems allocation of HEMS resources may need to use a different geometrical model (elliptical isochromes) to determine the optimum site for air medical resources.\textsuperscript{344}

\textit{Transport-time criteria for HEMS deployment}

Since any distance-based triage parameter is largely a surrogate for time, it is sensible to consider whether time can itself be used as a triage criterion. The previously noted \textit{caveat} regarding where the time endpoint should be measured – HEMS crew arrival at patient vs. patient arrival at tertiary care – comes into play when considering time goals. A Norwegian group has published logistics analyses based upon time from call to HEMS crew arrival at the patient (they used 30- and 45-minute cutoffs).\textsuperscript{345} Most, however, tend to use the time from the patient’s location to the receiving center. Regardless of the definition, time in some form plays a role in most HEMS activations. This monograph subsection highlights some proposed time-based criteria and related issues.

Considering trauma cases first, time-based criteria are mentioned in many studies and consensus statements. In the USA’s interagency government panel on HEMS dispatch, the consensus conclusion was that aircraft should be dispatched to trauma scenes based on time savings for patients who met the CDC’s Field Triage guidelines’ anatomic or physiologic criteria for trauma center care.\textsuperscript{346} Specific benchmarks for defining “significant time savings” in trauma HEMS dispatch are found in publications such as the following:

- In the USA, a nationwide NTDB analysis of half-dozen years of trauma cases concluded that HEMS improved outcome over GEMS when prehospital transport times were in the range of 6-30 minutes; the greatest HEMS benefit (80\% increase in survival odds) was seen with GEMS transport times in the range of 16-20 minutes.\textsuperscript{9}
- A Scottish group suggests that for head-injury cases, HEMS should be used when GEMS times exceed 30 minutes.\textsuperscript{347}
- English investigators have proposed that scene HEMS response be reserved for suitably critical cases (\textit{e.g.} patients with airway issues, shock, head or facial injury) for which ground transport to appropriate trauma centers would require more than 45 minutes.\textsuperscript{329}
As compared the use of distance criteria, which can be clearly assessed and even mapped for a given region, time-based HEMS triage criteria are more subject to estimation error. Subjectivity comes into play both at the time of a given triage decision, and in after-the-fact utilization review. The use of HEMS in urban settings is particularly problematic, because distances involved are usually small, yet traffic considerations can create long ground transports. One obvious mistake in assessing urban HEMS use is the retrospective assignation, based upon estimation of travel times, of theoretical ground EMS times. This approach (as used by many investigators) ignores the critical need to ascertain why HEMS was requested in a given circumstance – an ascertainment that is important since HEMS dispatch often occurs due to extraordinary traffic/travel situations unapparent on retrospective view.

Even for interfacility transports, which should seemingly be more predictable (since the “runs” are repeated frequently over time), close assessment of predicted vs. actual time savings can yield surprising results. Perhaps the best demonstration of this comes from logistics research based at the University of Wisconsin’s 20-hospital network. When assessing HEMS and GEMS transports into the tertiary center, investigators found that HEMS saved time for transports at all distances – for close-in hospitals HEMS saved just 10 minutes (potentially of clinical significance) whereas for other hospitals HEMS saved up to 45 minutes. The results were surprising because many of the referring facilities had GEMS based on-site for transports. Noting that theoretical immediate availability of GEMS units understandably did not always translate into rapid response, the Wisconsin group advised systems look carefully at actual (rather than presumed) travel times when setting up time-based HEMS triage.

Unwanted surprises on time-related endpoints are not restricted to GEMS. For HEMS, one of the most common hidden time costs is incurred when referring and/or receiving hospital’s HEMS landing sites are placed distant from clinical units. The lost time (not to mention the added transport leg) can be significant, as reported by findings from around the world:

- In an Ontario study in which referring and receiving hospitals lacked on-site helipads, HEMS did not appear to save time over GEMS when measured from the time of transport decision to trauma center arrival. The Canadians concluded that GEMS vs. HEMS transport times were often significantly influenced by non-distance factors such as helipad placement.

- Research from the U.K. has also noted time loss due to remote helipad placement, incorporating into HEMS dispatch guidelines the adjudication as to whether the receiving hospital’s helipad lies within a “trolley’s push” of the ED.

- Other Europeans (in Hungary) have concurred that HEMS’ time benefits are reliably achieved only if referring and receiving hospitals have ready access to helipads.

- The USA-based National Association of EMS Physicians is in agreement with the time-savings benefits of ready access to helipads.

The information regarding helipad placement is but one of many factors other than pure distance, that can affect transport time. Estimated time benefits of HEMS must take into account all factors that can play into total time required for HEMS and GEMS transport; accurate assessment of potential transport-mode time differences can only be made with a comprehensive view of time issues.
Section 7: NAEMSP Guidelines for Air Medical Dispatch

This section reproduces the National Association of EMS Physicians’ position statement outlining criteria for dispatch of HEMS. These NAEMSP HEMS guidelines are freely available on the USA-based association’s website (http://www.naemsp.org/Pages/Standards-and-Clinical-Practices.aspx).

The guidelines, co-authored by this monograph’s author nearly two decades ago, were essentially a cut-and-paste of the HEMS use guidelines then in use at the author’s Massachusetts HEMS program (Boston MedFlight, Executive Director Suzanne K. Wedel MD). The NAEMSP guidelines’ provenance is mentioned in order to provide context for this monograph’s report that the criteria have been perhaps justifiably criticized as overly broad, outdated, and inadequately supported by available evidence.

Potential shortcomings aside, the guidelines presented here remain those promulgated by a leading scientific and clinical association in the world of prehospital care. The NAEMSP guidelines have also been endorsed by the Air Medical Physicians Association and the American Academy of Emergency Medicine. It would appear that the NAEMSP guidelines serve as a reasonable starting point for regions working to develop their own HEMS dispatch criteria.

Just as the adaptation of NAEMSP (or any) HEMS dispatch guidelines to regional needs is important, the success or failure of guidelines in optimizing use of air medical resources is dependent on a vigorous a posteriori utilization review process. The review process can identify both over- and undertriage, and guide modifications to regional criteria for HEMS use.

General considerations

1. Patients requiring critical interventions should be provided those interventions in the most expeditious manner possible.
2. Patients who are stable should be transported in a manner which best addresses the needs of the patient and the system.
3. Patients with critical injuries or illnesses resulting in unstable vital signs require transport by the fastest available modality, and with a transport team with appropriate level of care capabilities, to a center capable of providing definitive care.
4. Patients with critical injuries or illnesses should be transported by a team that can provide intratransport critical care services.
5. Patients who require high-level care during transport, but do not have time-critical illness or injury, may be candidates for ground critical care transport (i.e. by a specialized ground critical care transport vehicle with level of care exceeding that of local EMS) if such service is available and logistically feasible.

Comparative assessment of air transport modes

Rotor-wing: Advantages
- In general, decreased response time to the patient (up to approximately 100 miles’ distance depending on logistics such as duration of ground transfer leg)
- Decreased out-of-hospital transport time
- Availability of highly trained medical crews and specialized equipment

Rotor-wing: Disadvantages
- Weather considerations (e.g. icing conditions, weather minimums)
- Limited availability as compared to ground EMS

Fixed-wing: Advantages
- In comparison to rotor-wing, decreased response time to patients when transport distances exceed approximately 100 miles
- In comparison to ground transport, decreased out-of-hospital transport time
- Availability of highly trained medical crews and specialized equipment
- In comparison to rotor-wing, less susceptibility to weather constraints
Fixed-wing: Disadvantages

- Requires landing at airport, with two extra transport legs between airports and the patient origin and destination
- In comparison to ground transport, more subject to weather-related unavailability (e.g. icing, snow)
- Overall, less desirable as a transport mode for severely ill or injured patients (though extenuating circumstances may modify this relative contraindication to fixed-wing use)

**Logistics issues that may prompt the need for air medical transport**

Access and time/distance factors

- Patients who are in topographically hard-to-reach areas may be best served by air transport.
- In some cases, patients may be in terrain (e.g. mountainside) not easily accessible to surface transport.
- Other cases may involve need for transfer of patients from island environs, for whom surface water transport is not appropriate.
- Patients in some areas (e.g. in the western USA) may be accessible to ground vehicles, but transport distances are sufficiently long that air transport (by rotor-wing or fixed-wing) is preferable.

Systems considerations

- In some EMS regions, the air medical crew is the only rapidly available asset that can bring a high level of training to critical patients. In these systems, there may be lower threshold for air medical dispatch.
- Systems in which there is widespread ALS coverage, but such coverage is sparse, may see an area left "uncovered" for extended periods if its sole ALS unit is occupied providing an extended transport. Air medical dispatch may be the best means to provide patient care and simultaneously avoid deprivation of a geographic region of timely ALS emergency response.
- Disaster and mass casualty incidents offer important opportunities for air medical participation. These roles, too complex for detailed discussion here, are outlined elsewhere.

**Scene response (primary missions)**

In some cases (e.g. flail chest), the diagnosis can be clearly established in the prehospital setting; in other cases (e.g. cardiac injury suggested by mechanism of injury and/or cardiac monitoring findings) prehospital care providers must use judgment and act on suspicion.

Absent unusual logistical considerations as an overriding factor, scene air response involves rotor-wing vehicles rather than airplanes.

As a general rule, air transport scene response should be considered more likely to be indicated when use of this modality, as compared with ground transport, results in more rapid arrival of the patient to an appropriate receiving center or when helicopter crews provide rapid access to advanced level of care (e.g. when a ground BLS team encounters a multiple trauma patient requiring airway intervention).

**Trauma:** Scene response to injured patients probably represents the mode of helicopter utilization with the best supporting evidence.

1. General and mechanism considerations
   - Trauma Score <12
   - Unstable vital signs (e.g. hypotension or tachypnea)
   - Significant trauma in patients <12 years old, >55 years old, or pregnant patients
   - Multisystem injuries (e.g. long bone fractures in different extremities; injury to >2 body regions)
   - Ejection from vehicle
   - Pedestrian or cyclist struck by motor vehicle
   - Death in same passenger compartment as patient
   - Ground provider perception of significant damage to patient's passenger compartment
   - Penetrating trauma to the abdomen, pelvis, chest, neck, or head
   - Crush injury to the abdomen, chest, or head
2. Neurologic considerations
   - Glasgow Coma Scale score < 10
   - Deteriorating mental status
   - Skull fracture
   - Neurologic presentation suggestive of spinal cord injury

3. Thoracic considerations
   - Major chest wall injury (e.g. flail chest)
   - Pneumothorax/hemothorax
   - Suspected cardiac injury

4. Abdominal/pelvic considerations
   - Significant abdominal pain after blunt trauma
   - Presence of a "seatbelt" sign or other abdominal wall contusion
   - Obvious rib fracture below the nipple line
   - Major pelvic fracture (e.g. unstable pelvic ring disruption, open pelvic fracture, or pelvic fracture with hypotension)

5. Orthopedic/Extremity considerations
   - Partial or total amputation of a limb (exclusive of digits)
   - Finger/thumb amputation when emergent surgical evaluation (i.e. for replantation consideration) is indicated and rapid surface transport is not available
   - Fracture or dislocation with vascular compromise
   - Extremity ischemia
   - Open long-bone fractures
   - Two or more long bone fractures

6. Major burns
   - >20% body surface area
   - Involvement of face, head, hands, feet, or genitalia
   - Inhalational injury
   - Electrical or chemical burns
   - Burns with associated injuries
   - Patients with near drowning injuries

Non-trauma: At this time the literature support for primary air transport of noninjured patients is limited to logistics considerations. It is conceivable that clinical indications for scene air response may be identified in the future. However, at this time prehospital providers should incorporate logistical considerations, clinical judgment, and medical oversight in determining whether primary air transport is appropriate for patients with non-trauma.

Interfacility transports (secondary missions)

Indications for HEMS transport from one hospital to another (i.e. secondary missions) are best summarized as being present when: 1) patients have diagnostic and/or therapeutic needs which cannot be met at the referring hospital, and 2) factors such as time, distance, and/or intratransport level of care requirements render ground transport non-feasible.

Trauma: Injured patients constitute the diagnostic group for which there is best evidence to support outcome improvements from air transport.

Depending on local hospital capabilities and regional practices, any diagnostic consideration (suspected, or confirmed as with referring hospital radiography) listed above under "scene" guidelines may be sufficient indication for air transport from a community hospital to a regional trauma center.

Additionally, air transport (short or long-distance) may be appropriate when initial evaluation at the community hospital reveals injuries (e.g. intra-abdominal hemorrhage on abdominal computed tomography) or potential injuries (e.g.
Aortic trauma suggested by widened mediastinum on chest X-ray; spinal column injury with potential for spinal cord involvement) requiring further evaluation and management beyond the capabilities of the referring hospital.

**Cardiac:** Due to regionalization of cardiac care and the time-criticality of the disease process, patients with cardiac diagnoses often undergo interfacility air transport. Patients with the following cardiac conditions may be candidates for air transport:

- Acute coronary syndromes with time-critical need for urgent intervention (*e.g.* cardiac catheterization, intra-aortic balloon pump placement, emergent cardiac surgery) unavailable at the referring center
- Cardiogenic shock (especially in need of ventricular assist devices or intra-aortic balloon pumps)
- Cardiac tamponade with impending hemodynamic compromise
- Mechanical cardiac disease (*e.g.* acute cardiac rupture, decompensating valvular heart disease)

**Critically ill medical or surgical patients:** These patients generally require a high level of care during transport, may benefit from minimization of out-of-hospital transport time, and may also have time-critical need for diagnostic or therapeutic intervention at the receiving facility. Ground critical care transport is frequently a viable transfer option for these patients, but air transport may be considered in circumstances such as the following examples:

- Pre-transport cardiac/respiratory arrest
- Requirement for continuous intravenous vasoactive medications or mechanical ventricular assist to maintain stable cardiac output
- Risk for airway deterioration (*e.g.* angioedema, epiglottitis)
- Acute pulmonary failure and/or requirement for sophisticated pulmonary intensive care (*e.g.* inverse-ratio ventilation) during transport
- Severe poisoning or overdose requiring specialized toxicology services
- Urgent need for hyperbaric oxygen therapy (*e.g.* vascular gas embolism, necrotizing infectious process, carbon monoxide toxicity)
- Requirement for emergent dialysis
- Gastrointestinal hemorrhages with hemodynamic compromise
- Surgical emergencies such as fasciitis, aortic dissection or aneurysm, or extremity ischemia
- Pediatric patients for whom referring facilities cannot provide required evaluation and/or therapy

**Obstetric:** In gravid patients, air transport's advantage of minimized out-of-hospital time must be balanced against the risks inherent to intratransport delivery. If transport is necessary in a patient in whom delivery is thought to be imminent then a ground vehicle is usually appropriate, although in some cases the combination of clinical status and logistics (*e.g.* long driving times) may favor use of an air ambulance. Air transport may be considered if ground transport is logistically not feasible and/or there are circumstances such as the following:

- Reasonable expectation that delivery of infant(s) may require obstetric or neonatal care beyond the capabilities of the referring hospital
- Active premature labor with estimated gestational age <34 weeks or estimated fetal weight <2000 g
- Severe pre-eclampsia or eclampsia
- 3rd-trimester hemorrhage
- Fetal hydrops
- Maternal medical conditions (*e.g.* heart disease, drug overdose, metabolic disturbances) exist, which may cause premature birth
- Severe predicted fetal heart disease
- Acute abdominal emergencies (*i.e.* likely to require surgery) with estimated gestational age <34 weeks or estimated fetal weight <2000 g

**Neurological:** In addition to those with need for specialized neurosurgical services, this category is being expanded to include patients requiring transfer to specialized stroke centers. Examples of neurological conditions where air transport may be appropriate include:

- CNS hemorrhage
- Spinal cord compression by mass lesion
- Evolving ischemic stroke (i.e. potential candidate for lytic therapy)
- Status epilepticus

**Neonatal:** Regionalization of neonatal intensive care has prompted the development of specialized (air and/or ground) services focusing on transport for this population. Given the fact that, in neonates, rapid transport is often less of a priority than (time-consuming) stabilization at referring institutions, some systems have found that the best means for incorporating air medical vehicles into neonatal transport is to use them to rapidly get a stabilization and transport team to the patient; the actual patient transport is then performed by a ground vehicle. In some systems, patients are transported (usually with a specialized neonatal team) by air when the ground transport out-of-hospital time exceeds 30 minutes. Examples of instances where air medical dispatch may be appropriate for neonates include:

- Gestational age <30 weeks, body weight <2000 g, or complicated neonatal course (e.g. perinatal cardiac/respiratory arrest, hemodynamic instability, sepsis, meningitis, metabolic derangement, temperature instability)
- Requirement for supplemental oxygen exceeding 60%, continuous positive airway pressure (CPAP), or mechanical ventilation
- Extrapulmonary air leak, interstitial emphysema, or pneumothorax
- Medical emergencies such as seizure activity, congestive heart failure, or disseminated intravascular coagulation
- Surgical emergencies such as diaphragmatic hernia, necrotizing enterocolitis, abdominal wall defects, intussusception, suspected volvulus or congenital heart defects

**Other:** Air medical dispatch may also be appropriate in miscellaneous situations:

- Transplant
  - Patient with criteria for brain death and air transport is necessary for organ salvage
  - Organ and/or organ recipient requires air transport to the transplant center in order to maintain viability of time-critical transplant
- Search-and-rescue operations
  - These operations are generally outside the purview of medical air medical transport services, but in some instances helicopter EMS may participate in such operations.
  - Since most search-and-rescue services have limited medical care capabilities, and since most air medical programs have similarly limited search-and-rescue training, cooperative effort is necessary for optimizing patient location, extrication, stabilization, and transport.
- Cardiac arrest
  - Patients known to be in cardiac arrest are rarely candidates for air medical transport.
  - An NAEMSP position paper has addressed situations in which resuscitation efforts should be ceased in the field for adult non-traumatic cardiac arrest victims. In such cases air transport should not be considered an alternative to discontinuing (futile) efforts at resuscitation.
  - In situations where patients are in cardiac arrest and do not meet local criteria for cessation of resuscitative efforts, or in jurisdictions in which prehospital providers cannot cease such efforts, air transport is an option only in rare cases (e.g. pediatric cold-water drowning where HEMS transport to cardiac-bypass center is considered).

**Questions that can assist in determining appropriate transport mode**

1. Does the patient's clinical condition require minimization of time spent out of the hospital environment during the transport?
2. Does the patient require specific or time-sensitive evaluation or treatment that is unavailable at the referring facility?
3. Is the patient located in an area that is inaccessible to ground transport?
4. What are the current and predicted weather situations along the transport route?
5. Is the weight of the patient (plus weight of required equipment and transport personnel) within allowable ranges for air transport?
6. For interhospital transports, is there a helipad and/or airport near the referring hospital?

7. Does the patient require critical care life support (e.g. monitoring personnel, specific medications, specific equipment) during transport, that is not available with ground transport options?

8. Would use of local ground transport leave the local area without adequate EMS coverage?

9. If local ground transport is not an option, can the needs of the patient (and the system) be met by an available regional ground critical care transport service (i.e. specialized surface transport systems operated by hospitals and/or air medical programs)?
Summary and conclusions

The preponderance of scientific evidence supports a conclusion that HEMS transport is a necessary and important component of many EMS systems. Benefits are accrued to patients, as well as healthcare regions.

Ongoing criticism of HEMS utilization is not without basis. Specifically, the inexact science of triage has been, and continues to be, a major hindrance to efforts at optimally deploying helicopter transport resources. While researchers should maintain efforts directed toward more accurate identification of situations in which HEMS is likely to be helpful, regions in which air transport is used should also work to insure that triage guidelines exist – and that they're followed.

Ongoing efforts in clinical HEMS investigation should include focus on specific instances in which air medical response may be associated with improvements in mortality, morbidity, or other endpoints (including cost savings). Specific attention should be paid not only to costs of HEMS, but to differential costs of air medical versus alternative transport (e.g. by ground critical care teams).

Fortunately, although HEMS utilization in the USA and abroad is associated with overtriage, data indicate sufficiently favorable cost-effectiveness to continue HEMS use while the science of out-of-hospital care improves. With the caveat that safety remains the highest priority, ongoing investigational focus on cost-beneficial care should improve HEMS utilization and incorporation of air transport into healthcare systems.

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