HELICOPTER EMS

OUTCOMES RESEARCH, COST-EFFECTIVENESS, & TRIAGE

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SECTION I. INTRODUCTION

This discussion strives to overview evidence addressing benefits accrued by utilization of helicopter EMS (HEMS). The primary goal will be 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.

The monograph is divided into Sections. After the Introduction and Objectives (Sections I and II), the discussion continues in Section III with background information (e.g. a description of TRISS) that is provided to facilitate interpretation of HEMS studies. Section IV introduces the HEMS outcomes literature, providing annotations for a selection of important publications. Sections V and VI outline potential HEMS benefits to both patients and EMS regions. Section VII incorporates the previous sections’ lessons into an introduction to HEMS cost-effectiveness. Section VIII commences consideration of the critical and controversial subject of triage, which topic is also covered in Section IX’s reproduction of the air medical utilization guidelines of the National Association of EMS Physicians (NAEMSP). Some conclusions about HEMS outcomes research, cost-effectiveness, and triage are summarized in Section X. The reference listing, in Section XI, concludes the monograph.

The HEMS outcome debate’s longevity and vigor constitute sufficient impetus for evidence-based exploration of whether there is air transport benefit. Fortunately, some detailed exploration of existing data has been executed. One excellent example is a 2007 report from the independent Institute of Health Economics, prepared for the Canadian health ministry in Alberta. These authors, after reviewing all available studies from the year 2000, concluded: “Overall, patients transported by helicopter showed a benefit in terms of survival, time interval to reach the healthcare facility, time interval to definite treatment, better results, or a benefit in general.” A similar conclusion has been reached by the authors (including this monograph’s author) of a Cochrane review of HEMS response for scene trauma (not yet published).

If HEMS is associated with advantages then it is important to try and optimize use of the resource, by identifying cases in which benefit is most likely to occur. Some investigators have assessed regional costs of HEMS to be no higher than those associated with response-time-equivalent (multivehicle) ground critical care coverage. However, it is quite likely that HEMS’ nature of concentrating resources on a few high-cost vehicles will translate into a perception of air medical transport as being a high-cost option.

It is undoubtedly the case that HEMS’ presence continues to grow. One recent overview estimated that in the U.S., 753 helicopters (and 150 dedicated fixed-wing aircraft) are in EMS service, providing about 3% of all ambulance transports. While individual programs’ mission profiles vary, an average U.S. HEMS program performs 54% interfacility transports, 33% scene runs, and 13% “other” mission types (e.g. neonatal, pediatric, transplant-related).

Since few would argue that HEMS benefit is always predicated solely on time and logistics, any consideration of HEMS outcomes evidence 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” in order to encompass 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. For example, studies assessing prehospital intubation (ETI) have provided important – if unintended – insight into HEMS’ salutary impact on outcome.

Many questions remain unanswered about HEMS. However, there is a body of evidence addressing HEMS’ potential outcomes impacts, that is often paid insufficient attention by both sides in the HEMS debate. It is hoped that this discussion will help interested parties to better understand the evidence pertinent to the HEMS outcomes dialogue.
SECTION II. DISCUSSION OBJECTIVES AND MONOGRAPH CONTENTS

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:

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SECTION III. OUTCOMES ASSESSMENT IN HEMS

This section covers the impact HEMS use has on patients, EMS systems, and regionalized care networks. While patient-centered outcomes are of course most important, the other “outcomes benefits” also contribute to potential justification for including HEMS in a system.

A. A note on “outcomes”

Various outcomes will be visited in detail later in this review, but it is appropriate to commence with a brief word on what constitutes an “outcome.” This review will address primary, secondary, and surrogate outcomes.

1. Primary outcome variables: Survival and functional outcome

   - The most important outcome for HEMS studies is that of functional survival. This is the primary outcome addressed in most studies referenced in this review. Since survival to hospital discharge in a persistent vegetative state is different from functional survival, consideration of neurological condition should be (and usually is) incorporated into survival definition.

   - Discussions of HEMS’ potential utility often mention safety. The line of thinking, often advanced by those who believe HEMS is significantly overused, is that against any potential benefit accrued by HEMS should be weighed the risks associated with air transport. Some points on this important subject follow:
     - The first and most important point is that HEMS safety is indeed a critical issue, and is in fact the industry’s self-identified number one priority. Air medical transport safety has clearly deserved the attention it has garnered from experts such as Dr. Ira Blumen of the University of Chicago.9
     - While safety is critical, the overall data indicate very low patient risks associated with air transport crashes. In fact, some reviewers of available data have concluded that fatality rates per mile traveled are lower for HEMS (0.4 per million air miles) than for ground EMS (1.7 per million ground miles traveled).1 In terms of patient death rates, an Australian report10 overviewing a decade of HEMS transports (1992-2002) found that helicopter accidents resulted in one patient death per 50,164 missions. Similarly, a German series comprising six years (1999-2004) of HEMS transports, discovered a decreasing crash rate and zero patient deaths during the study period.11 Estimates for U.S. helicopter operations, based upon over two decades of data, report less than one patient death per 100,000 missions.3 A recent report from the U.K. overviewed 5 years (1999-2004) of road and helicopter ambulance fatalities: there were zero HEMS-associated fatalities and 40 fatalities in accidents involving ground EMS vehicles.12
     - Unfortunately, given the uncertainty surrounding ground EMS fatality rates, a true comparison of ground vs. HEMS transport safety is difficult to make.
       - Experts on prehospital vehicle safety note: “Unlike helicopter and fixed-wing EMS incidents, little is known about ambulance crashes.”13
       - A “News & Perspective” piece in the Annals of Emergency Medicine (Volume 56, Number 5) reported a safety-related interview with Nadine Levick MD MPH, the Chair of the EMS Transport Safety Subcommittee of the National Academies Transportation Research Board. Levick estimated that each year, 9,000 annual ground EMS crashes result in 50+ deaths and 3500+ serious injuries, costing over $500 million. Dr. Levick contends that “ambulances are the most lethal vehicle on the road both per mile traveled and per vehicle.” A study on adverse events in ground EMS14 examined 2 years of national tort claims and identified a rate of prehospital ground transport deaths similar to that reported by Dr. Levick.
       - Although safety is undeniably critical, the available data show that – considered overall – HEMS transport accrues patient survival numbers that far outstrip the (rare) occurrence of transport-associated death.
       - One U.S. group provides what may be the best perspective, noting that the 6500+ ambulance crashes (and 32+ deaths) per year doesn’t mean that ground EMS is unsafe – but it does mean that a rational examination of HEMS safety risks and benefits must consider both air and ground accidents.13

2. Secondary and surrogate outcome variables include some of the following parameters.

   - Though listed here as a secondary variable, pain relief has been considered by many EMS experts as a stand-alone (i.e. primary) outcome for prehospital care.15
   - One group of secondary variables encountered in the medical literature deals with lengths of stay in various hospital departments (e.g. ICU stay). The problems attendant to use of these endpoints are well-known to
clinical researchers; length-of-stay is impacted by many factors well downstream from transport modality. Nonetheless, an illustrative HEMS study\textsuperscript{16} suggests that, as compared with ground-transported cardiac patients, those transported by air had a 2-day decrease in hospital length of stay due to improved myocardial salvage. That study is the exception to a general rule that HEMS literature focuses more on mortality and other surrogate endpoints (see below) rather than addressing hospital lengths of stay.

- Studies assessing HEMS’ impact on surrogate endpoints constitute an important set of contributions to the literature. Surrogate variables tend to be physiologic (e.g. hypoxemia, hypercapnia, hypotension) or logistic (e.g. prehospital time, time to advanced care) parameters that have firm evidence basis for use as endpoints. Some surrogate outcomes are not likely to be testable in terms of precise mortality benefit; an example would be the ability of highly trained HEMS crews to streamline interfacility transports of ruptured abdominal aortic aneurysm patients by taking them directly to receiving hospitals’ operating rooms.\textsuperscript{17} While some secondary and surrogate endpoints lack universal acceptance as impacting functional outcome, there is solid evidence basis for others (e.g. hypoxemia in brain injured patients).\textsuperscript{18}
- An emerging view is that patient safety initiatives in HEMS have resulted in low incidence of adverse events during air medical transport. Given the importance of patient safety, and the increasing attention to this as an “outcome,” preliminary work such as that by MacDonald et al\textsuperscript{19} is of vital import.

B. Nontrauma outcomes analysis is at best an inexact science.

Outcomes analysis for nontrauma is more complicated than that for trauma. To a large degree, nontrauma outcomes analysis relies on secondary and surrogate endpoints.

1. The main problem with outcomes analysis in non-trauma patients consists of two closely linked parts. First, experts in many countries, even where there is debate over HEMS’ effectiveness, are in agreement that a randomized controlled trial of HEMS vs. ground transport is not currently feasible. Second, since HEMS-triaged patients tend to be of higher acuity than ground-transported patients, outcomes analysis has to be acuity-adjusted. Unfortunately, there is no consistently reliable means of acuity adjustment for nontrauma patients.

2. A lesser problem, but still no small barrier, is that the nontrauma transport population comprises disparate diagnostic groups (e.g. pregnancy, acute coronary syndromes, epiglottitis, stroke, poisoning). Such disparity translates into small numbers for a single diagnosis. This in turn leads to biostatistical difficulties in detecting a small but clinically important benefit in the less commonly encountered patient types.

3. As a result of the issues noted above, use of HEMS for nontrauma patients has an evidence base that is, compared to that for trauma transport, less concrete. Nonetheless, there is evidence of various sorts. Absent controlled trials, some consideration should be given to expert opinion and even (for unusual diagnoses) case reports. These reports are often based upon time savings accrued with HEMS. For example:

a. An editorial\textsuperscript{20} appearing in Chest, the journal of the American College of Chest Physicians, observed that “In many communities, emergency air medical systems have become an integral part of the practice of cardiology and critical care medicine.” The authors go on to aver that “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.” Reports outlining extension of percutaneous coronary intervention (PCI) to community hospitals include incorporation of HEMS into systems planning, as a necessary back-up in cases where urgent CABG is required.\textsuperscript{21} It’s increasingly well known that time savings – in the manner that may be achieved by judicious HEMS use – can be helpful: each 30 minutes’ additional ischemia time increases mortality by 8-10\%.\textsuperscript{22} Additionally, work from the TRANSFER-AMI group suggests that expedited transfer for mechanical intervention after community hospital lysis is associated with a 50% reduction in the 30-day composite endpoint (death, reinfarction, recurrent ischemia/reinfarction, CHF, or shock).\textsuperscript{23} It seems likely HEMS will sometimes be a valuable option for some patients receiving this combined-therapy approach.

b. Similar to the situation with integration of HEMS into cardiac care systems is the rapidly solidifying role for air transport in stroke care. A Resource Document for a position statement of the National Association of EMS Physicians recommends air transport of stroke patients if the closest fibrinolytic-capable facility is more than an hour away by ground.\textsuperscript{24} The American Stroke Association Task Force on Development of Stroke Systems\textsuperscript{25} identified HEMS as an important part of stroke systems. The report states “Air transport should be considered to shorten the time to treatment, if appropriate.” Authors writing about the utility of HEMS in stroke (and also cardiac) care systems generally refer to the ability, addressed in detail later in this discussion and bolstered by logistics studies, of HEMS to “extend the reach” of tertiary care centers providing time-critical care.\textsuperscript{26,27} A potential role for time-critical transport in improving
stroke outcomes is suggested by the pooled analysis revealing a stepwise outcomes improvement associated with each 90-minute improvement in lysis time (to 270 minutes).  

2.8. Another type of difficult-to-categorize (and equally hard to research) “outcomes” publication is the case report. As an example of the many such reports, there is a description of lifesaving HEMS use in a 32 year-old ARDS patient who received inhaled prostacyclin during an air medical transport that was deemed to be critical to that patient’s survival. Others, in both the U.S. and abroad, have highlighted the occasional utilization of HEMS (scene runs) to enable stroke patients to reach specialized centers in time to receive outcome-improving lytic therapy. As an example, a Canadian group described use of air transport to get critically needed antidotes (fomepizole in one patient, Digibind in another) to patients up to 6 hours faster than would have been the case had therapy been delayed to ultimate arrival at receiving centers. 

The evidence found in expert/consensus opinion and case reports is nowhere near definitive. However, those interested in researching the potential utility of HEMS would do well to consider that, particularly for some nontrauma diagnoses, there are different levels of evidence that, while flawed, shouldn’t be ignored.

C. Trauma outcomes analysis

Trauma outcomes analysis has a major advantage over nontrauma outcomes analysis in that there are more transported patients with trauma; this allows for more robust statistical methods. Also, there are many scoring systems (e.g. Glasgow Coma Score [GCS], Trauma Score [TS], Injury Severity Score [ISS]) that can be used to stratify patient acuity.

1. The capability of scoring systems to adjust, at least partially, for differences in patient acuity translates into an improved ability to combine patients from many HEMS programs and thus conduct multicenter research. Since most (though not all) HEMS programs transport a majority of trauma patients, the larger numbers for injured patients mean that it’s easier to conduct outcomes research on trauma patients than on other populations.

2. The reader is expected to be familiar with most of the basic scoring systems, such as GCS and TS, but one method for acuity adjustment – TRISS – is a bit more complicated. TRISS is frequently encountered in the HEMS literature, and since its application (and misapplication) has important implications for appropriate interpretation of many trauma outcomes studies, the method will be introduced here. Given some understandable controversy around use of TRISS it is worth noting that, despite the methods’ shortcomings, there is no clearly preferable methodology: trauma systems experts continue to believe that TRISS is the gold standard for predicting outcomes in trauma patients. Thus, some time spent learning TRISS fundamentals may be useful. (For detailed explanation of TRISS, readers are referred to a more definitive source such as the work of Boyd et al.)

2.8. a. TRISS incorporates physiologic (TS), anatomic (ISS), mechanism (blunt vs. penetrating) and age (55 years as cutoff) covariates into a logistic regression model with mortality as the dependent variable.

2.8. b. TRISS uses the logistic model to calculate predicted mortality, incorporating β coefficients (the model’s “terms”) derived from analysis applied to the American College of Surgeons’ Multiple Trauma Outcome Study (MTOS) database.

2.8. c. Once the TRISS-predicted mortality has been calculated for the study population, the predicted mortality can then be compared to actual mortality.

2.8. d. It is not necessary to delve into the details of logistic regression to intuit that 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. In other words, it’s inappropriate to employ unadjusted TRISS methodology on a study group that’s significantly different from the MTOS source group from which TRISS coefficients were derived.

2.8. e. Given the information above, 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 casemix similarity. [N.B. As researchers increase focus on determining M statistics for a variety of populations, studies are demonstrating that – especially in non-U.S. locations – M statistics are substantially lower than levels appropriate for uncorrected TRISS use.]

2.8. f. 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.

2.8. g. When further stratification is necessary, or when M < .88, adjusted or standardized W can be calculated.

2.8. h. The last step is calculation of a Z statistic to test H0 of no difference between 0 and the calculated W.
Once TRISS’ applicability is confirmed, 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 papers use TRISS’ MTOS population to provide a “control” group; in other words, the investigators simply demonstrate that their 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.

- Because of the above-noted point, 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); other factors such as hospital care quality are thus accounted for (since they are the same for HEMS and ground patients). Such a study design can provide compelling evidence for air transport benefit if there is reduction in actual as compared to TRISS-predicted mortality for HEMS patients, but no reduction (or a significantly lesser one) is detected for those transported by ground. Furthermore, when all of the system variables are maintained the same, the mortality benefit from HEMS may be reliably estimated by assessing the absolute difference between mortality changes from TRISS associated with ground as compared to air transport. For instance, in a province-wide study in Nova Scotia, Mitchell et al 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%.

3. Use of either traditional (e.g. ISS) or TRISS systems provides the advantage of adjusting for injury acuity, but there is a limit to the ability of any scoring system to homogenize large groups of patients with disparate injuries. Such imperfection is not, per se, an indictment of the scoring systems, but consumers of the medical literature should keep in mind the varying (and sometimes substantial) potential for residual confounding due to acuity differences between air and ground-transported patients. These confounding variables (e.g. differences in GCS that are not adjusted for in comparative analysis) can substantially reduce, or even eliminate, the useful information that can be gleaned from HEMS studies. Furthermore, as is the case with any study in which confounders are identified, the identified confounding variables are only part of the problem – unidentified confounders are just as much a concern.

D. Study designs in HEMS literature

Given the above discussion on nontrauma and trauma research, and the difficulty with conducting prospective trials in this field, there are a relatively small number of study designs that have been used in evaluating outcomes in the HEMS literature. Of note, there is a major randomized controlled trial of HEMS response (vs. ground paramedic care) for head injury in New South Wales, Australia. The Head Injury Response Trial (HIRT) has completed enrollment, and the analysis of over 600 patients with ISS exceeding 15 is pending (personal communication, trial PI Alan Garner). Other than this trial, there are very few if any randomized data informing the HEMS debate. The types of studies follow:

1. Panel review studies involve assessment of HEMS patients by groups of medical specialists, with retrospective ascertainment of potential patient benefits. An example is employment of a Delphi technique to achieve a consensus conclusion about HEMS benefits in a given set of patients. The main strength of this design is that it is the easiest to complete (though conducting such a study in a methodologically rigorous fashion is harder than one would initially presume). Another “advantage” of this design (which is balanced by the disadvantage of bias) is that it maximizes the ability for outcomes assessment to take into account intangibles or difficult-to-quantify advantages of HEMS or ground transport. Of all of the HEMS study designs, this is perhaps the most likely to directly link the putative outcome improvements to specific interventions (e.g. intubation).

   The main weakness of this 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.

2. Air vs. ground cohort studies attempt to match acuity and other characteristics for HEMS and ground transported patients, and perform outcomes comparisons. The approach that is simplest (although the least useful) is the straightforward comparison of outcomes of patients undergoing HEMS transport to a given hospital, with the outcomes of patients who present primarily to that hospital. This has been executed for cardiac, obstetric, and neonatal patient populations, with findings that HEMS allows for outcomes equally as good as primary-presenting patients.

   Another cohort study design is assessment of outcomes in trauma patients stratified by TS, accounting for the injury mechanism and for demographic factors. A third approach might be the generation of multiple
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 needed to produce robust results. This is because the outcome of interest (mortality) is only 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, the relatively low cell counts (recall that data were split into multiple tables) translate into low study power: wide confidence intervals that are likely to cross the null value.

Some investigators have used matching to adjust for inherent acuity differences in HEMS mad 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. RTS, intubation).

Another method for analyzing cohort study data, is to incorporate the transport mode cohorts (air and ground) into a generalized linear model (GLM). Using dichotomous outcomes such as mortality, logistic regression can be used to explore the potential association between transport mode and outcome.

One of the GLM problems associated with having relatively low outcomes numbers (low mortality) is that models cannot incorporate as many covariates, as there are parameters that may confound the association transport modality and outcome. It’s preferable to have about 20 “outcomes” per covariate in a model, and it’s not uncommon for the number of deaths to be too low to allow for appropriate model-building. Propensity scoring allows a mechanism to include these confounders, in a single parameter (usually generated by logistic regression, and describing the “propensity” that certain types of patients will undergo helicopter transport). As described in more detail elsewhere, this mechanism can be effective in dealing with potential for confounding.

One 2011 Oklahoma population-based study used propensity scores along with ISS, RTS, and transport distance to model the association between HEMS and scene trauma mortality; the robustness of the HEMS-associated mortality improvement of 33% is strengthened by the use of propensity scores in the multivariate model.

3. **TRISS** studies, described in detail above, have as their basis a logistic regression model to test actual mortality vs. the outcome which is predicted (i.e. by the MTOS data), and in some cases to compare HEMS-group outcome improvement with outcome improvement found in ground-transported patients. An example of this type of study would be the “three-step” design first employed by Baxt et al in 1983. The steps are: 1) compare HEMS-transported patients’ actual to TRISS-predicted mortality, 2) compare ground-transported patients’ actual to predicted mortality, and 3) test the null hypothesis that mortality changes from predicted were similar in the air and ground cohorts. Baxt’s pioneering 1983 work could be said to have truly set the stage for the dozens of TRISS-based HEMS analyses that followed.

The advantage of TRISS studies is that they optimize use of an extremely large database (MTOS) that provides robust estimates for expected mortality, *given certain assumptions* (see discussion above). Like other multivariate models, TRISS also allows for simultaneous consideration of many variables. TRISS is not without a substantial amount of controversy, and some of the most often-quoted TRISS studies suffer from inappropriate use of the methodology (i.e. lack of using the standardized W statistic when M is too low). One of the risks of TRISS, common to some other complex multivariate models, is that it can take on the aura of a “black box” in which the results data appear concrete, but the methods of getting to those results are nebulous. Other quirks of TRISS methodology, such as substitution of normal physiological parameters for missing variables, are not a major problem as they predictably bias TRISS studies against HEMS.

4. **Safety/ complication** studies are perhaps not really outcomes studies, but they are related to the subject since they address whether certain populations are placed at particular risk by HEMS transport. Examples of this type of study are the retrospective analyses of post-thrombolysis HEMS transport of cardiac or stroke patients. These reports addressed the question of whether transport of such patients by air was associated with an increased risk of bleeding and other complications. Subsequent studies in myriad patient types have provided an increasing body of evidence supporting a contention that even patients of high acuity and tenuous stability, such as ventilated neonates, suffer no adverse effect from air as compared to ground transport modality.

The advantage of this study design is that it addresses easily understood, and (relatively) easily testable, notions regarding the potential for HEMS-associated harm (e.g. increased hemorrhage rates in post-lysis patients). This type of study is frequently useful when the debate surrounds whether HEMS actually increases mortality, but the safety/ complication studies are unhelpful for the more usual question of whether there is any benefit to air transport.

5. **Natural experiment** study “designs” are not usually prospectively defined plans. Rather, they are assessments of what happens when HEMS availability changes for a given region. There are only a few studies of this type, but
the available data are quite informative. In fact, the natural experiment design – if truly population-based and covering the same patient group before and after HEMS availability changes – can provide some of the most compelling evidence informing the HEMS debate.

Unfortunately, natural experiment studies can also be subject to the fatal flaw of selection bias. Specifically, if HEMS is discontinued, the “non-HEMS” analysis cohort (i.e. the group of ground-transported patients assessed after HEMS becomes unavailable) must include all patients who would have been transported by air, if such air transport were available. Methodology that fails to include the entire population of patients eligible for HEMS, predictably finds little mortality difference. Such was the case with the first HEMS natural experiment paper published. The authors’ determination 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 likely died) at the distant community hospitals.

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, in which state there was a situation in which some, but not all, hospitals 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). The impact of these results is attenuated by the possibility of residual confounding related to hospital commitment to trauma (i.e. hospitals with lesser commitment to overall trauma care would also be less likely to commit resources to keep HEMS).

The advantage of the natural experiment type of study lies in its potential to methodologically approximate the optimal (but largely unachievable) study design: the randomized controlled trial. 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 third natural experiment study has assessed changes in trauma mortality when HEMS availability changes in the direction of added helicopter coverage. Schiller et al 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.

A final version of the natural experiment is truly related to “nature” in that it assesses patients in whom weather (and to a lesser extent, mechanical/other issues) precluded HEMS response to cases in which air transport was requested. This study design is also subject to selection bias, since it’s not easy to include in the analysis, all of the patients in whom HEMS would have been used if available. However, a population-based analysis done in Canada overcomes that limitation. This Nova Scotia project found that HEMS, as compared to ground transport to Level I care, saved a statistically significant 5.6 lives per 100 transports.

6. As a relative of the “natural experiment” discussion, it should be pointed out that one type of such study would be a population-based analysis of trauma mortality with correlation to HEMS coverage. Trauma mortality in geographic regions with HEMS coverage is compared to mortality in areas that lack such coverage, but which are otherwise identical. Such research is not likely to be easy, and residual confounding (e.g. by quality of trauma care) would be a major problem. However, 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). The ADAMS data, like that from other trauma systems that clearly demonstrates mortality improvement in cases where HEMS transports to Level I centers, parallels the reports of utility of HEMS in stroke and cardiac systems. It is nearly impossible to tease out the HEMS contribution from the other components of good system care. However, some population-based systems studies such as one from Massachusetts, have concluded that HEMS utilization results in mortality reduction of 13-22%. For better or worse, these highly effective systems do not appear likely to perform randomized controlled trials of transport modality. In fact, trauma systems experts have written that when it comes to HEMS’ impact on mortality, “prospective randomized trials are simply not feasible or ethical.”

7. In some cases, HEMS’ effect on outcome is elucidated by studies that focused on different questions entirely. These “non-HEMS” studies are limited, in the sense that they didn’t intend to focus on HEMS, but such limitation may also be an advantage in that such studies tend to be executed by parties with no apparent “agenda” (one way or the other) with regard to the HEMS debate.

- One example of such a study is that conducted in Pennsylvania, in which investigators found HEMS ETI (but not ground EMS ETI) improved both survival and functional outcome in patients with head injuries. Editorialists 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."

- A trauma systems study from Oregon, with an intended focus on prehospital intubation, also finds strong evidence for HEMS-mediated outcomes improvement. In a methodologically rigorous 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.”

8. 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 et al 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.

9. As mentioned previously in the discussion on nontrauma outcomes literature, there are miscellaneous small-series and expert opinion types of reports, that suggest the possibility of outcomes improvement:
- A UK report contended that field thoracotomies performed by HEMS crews contributed to survival.
- With previously noted caveats about “expert opinion” as an evidence level, it is worth noting the opinion of trauma orthopedists who contend that urban HEMS use is justified “particularly for patients with spinal injuries” for reasons of rapid and smooth evacuation.
- Though the ability to extrapolate from anecdotal experience is limited, every HEMS operator can sympathize with the sentiments of one program director, a 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 surrogate outcomes, particularly with respect to issues such as analgesia practice and airway management-associated physiology. These reports are characterized by a consistent suggestion that HEMS transport and the associated advanced crew capabilities have salutary impact on a wide variety of clinically important variables.
  - As an example, in an investigation of rapid-sequence intubation (RSI) in severely head injured patients, HEMS ETI was found to be associated with improvements in blood pressure, oxygen saturation, and end-tidal carbon dioxide levels as compared with pre-ETI levels. Taken in isolation, this report is hardly surprising; the results are more relevant to the HEMS debate when they are considered in the light of many ground EMS reports of major peri-ETI physiologic derangements.
  - The most recent reports on prehospital air medical crew ETI continue to support the notion that HEMS ETI is similarly safe and effective as ETI in the acute care in-hospital setting. Additionally, recent prehospital airway research has bolstered arguments that, even when ETI is performed by ground ALS, HEMS transport improves outcome as compared with ground transport because of post-ETI ventilation practices.
SECTION IV. HEMS LITERATURE

This section is divided into an Overview, which provides some general information about the HEMS literature, and a Selected Papers subsection which highlights selected works. Many, but not all, of the papers are referenced elsewhere in this discussion and are thus included in the References. Those papers have been double-listed in this section, in an effort to provide readers with a more complete, single-location listing of papers categorized by patient population.

There is disagreement about the persuasiveness of the HEMS outcomes literature. However, there can be little argument that the past few decades’ volume of work, both supporting and refuting potential HEMS benefits, warrants attention from anyone interested in optimizing evidence-based provision of prehospital care. Definitive survey of all extant HEMS papers exceeds the scope of this discussion; the monograph instead aims to orient the reader to the pertinent literature and resources.

Though it addresses an area of medicine marked by controversy, the HEMS outcomes literature has been the subject of few systematic reviews. When the Air Medical Committee of the National Association of Emergency Services Physicians (NAEMSP) set out in 2001 to update the organization’s HEMS dispatch guidelines, there were no comprehensive HEMS outcomes reviews to aid preparation of evidence-based recommendations. Accordingly, the committee generated two systematic reviews of the 1980-2000 HEMS outcomes literature (one review addressing nontrauma and another trauma), which were published in Prehospital Emergency Care. These two articles were the foundation for the updated NAEMSP Guidelines for Air Medical Dispatch, which are discussed later and which have been endorsed by the Air Medical Physician Association (AMPA), the Association of Air Medical Services (AAMS), and the American Academy of Emergency Medicine [AAEM]. An additional paper, reviewing trauma and nontrauma outcomes literature published during 2000-03, was published in Prehospital Emergency Care in the summer of 2004. Another overview addressing 2004-06 literature is also found in Prehospital Emergency Care. These reviews and further updates through the current year are included on the website www.cctcore.org (the website for the Critical Care Transport Collaborative Outcomes Research Effort, a multicenter research group).

SELECTED ARTICLES WITH ANNOTATION

- **GENERAL — ARTICLES ADDRESSING MIXED-DIAGNOSIS PATIENT POPULATIONS**


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


   **Note** This study takes on the difficult (if not impossible) task of performing outcomes analysis on a diagnostically disparate group. Due to related drawbacks (e.g. use of an unvalidated scoring system to generate pooled acuity estimates), the authors acknowledge strong possibility of residual confounding due to air vs. ground acuity differences.


   **Note** This paper’s results provide important follow-up to the conclusions of Lindbeck et al (reference #1 above). HEMS utilization for patients who are post-arrest can be useful.

- **TRAUMA — SCENE TRAUMA TRANSPORTS**


   **Note** This was the first analytic attempt to determine whether HEMS was associated with mortality benefit. The incorporation of a ground control group is a particular strength of this paper. Dated ground unit capabilities (e.g. use of esophageal obturator airways) may limit the study’s current applicability, but such limitations do not completely negates the study results since contemporary HEMS crew capabilities continue to be largely ahead of those of ground EMS services (e.g. in the realm of prehospital ETI).

Note This multicenter study found a mortality improvement in all seven HEMS services assessed (the outcomes improvement compared to TRISS-predicted was statistically significant in five services), but the lack of a ground control group translated into failure to identify the HEMS contribution to good system performance.


Note Despite substantial potential for confounding by acuity differences (e.g. HEMS patients' GCS was lower than that of the ground group), this study made a cogent argument that HEMS has little mortality impact when used within a city with short ALS response and transport times.


Note This study compared HEMS “apples” to ground EMS “oranges” in the sense that the capabilities of the former service were far advanced (for example, 81% of HEMS patients and virtually none of ground patients were intubated). To the extent that its regional characteristics are generalizable elsewhere, the study bolsters arguments that HEMS can improve mortality in situations where ground EMS capabilities are limited or widely dispersed.


Note This oft-cited paper examined a subset of the larger group of patients later assessed by Younge et al (see reference 7 below). The exclusion criteria (e.g. discarding most trauma center transports and instead looking at transports to non-trauma centers), inclusion of three types of “HEMS” patients (including some transported by ground), and unusual outcomes definitions are among the paper’s serious methodologic flaws. The study’s outcomes validity is also thrown into question by the subsequent finding (by Younge et al) of the inappropriateness of using standard TRISS (as was done by these authors) in the studied population. This study’s prominent place in the HEMS debate probably has much to do with the fact that it is one of relatively few TRISS studies that have failed to identify a HEMS-associated mortality benefit.


Note This study’s patients had low acuity, hence there were low numbers in the mid- and high-range acuity subgroups. The authors found that in the injury acuity midrange (TS 5-12 and ISS 2-40), HEMS was associated with survival improvements in all eight subgroups but significance was achieved in only two. The authors’ conclusions — that low overall acuity meant need for improved triage — were reasonable, with the caveat that there was little discussion of logistics issues surrounding rural trauma transport (e.g. using HEMS service to quickly get ALS to an isolated patient, or to prevent an area’s losing of ALS during long-distance ground transport).


Note This study’s methodological complexity may account for the relative infrequency with which it 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. Importantly, survival benefit could have been due to HEMS, receiving facility characteristics, or some combination of the two.


Note With methodological shortcomings such as artificially calculated ground transport times and failure to adequately address important clinical findings such as the frequent HEMS crew performance of intubation (including, in some cases, after failed ground ALS attempts), this paper fails to make a compelling case for the common-sense notion that HEMS may not be useful in an urban setting.


Note This multivariate logistic regression analysis found that HEMS effects on survival varied depending on ISS levels. Since both HEMS proponents and detractors agree that air transport won’t help either the trivially or mortally injured, the study’s results are in line with common sense. There was no mortality benefit for the lowest- or highest-
acuity ISS groups (ISS <15 or >61), but for the other three groups HEMS was associated with a 2.1-2.6x increase in survival likelihood. Unfortunately, since ISS can only be calculated retrospectively (after all injuries are characterized) the results shed little light on triage.


**Note** This study assessed severe head injury outcome for patients receiving "basic" (i.e. basic life support plus intravenous access) vs. "advanced" (i.e. anesthesiologist-staffed HEMS) prehospital care. The authors' explanation of their findings and discussion of possible confounders of their negative results is particularly thoughtful. Interestingly, the paper's negative results are inconsistent with a previous paper published by some of the same authors, assessing HEMS in the same region (Nardi et al, reference 4 above).


**Note** This methodologically rigorous (and complicated) study found positive effects due to deployment of a helicopter-based physician-nurse team to trauma scenes around Rotterdam. The authors concluded there is significant HEMS benefit, and their data support their inference as applied to their system. The study's external generalizability may be attenuated by the Dutch practice of HEMS crews' stabilizing patients who are subsequently transported by ground (often without HEMS crew attendance; see comment for Frankema et al reference 14 below).


**Note** This was the first study (published in full length form) addressing the "natural experiment" of what happened when HEMS became unavailable in a region (in this case, due to financial pressures). The data are severely limited by selection bias; 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) basically executed the same study design, and came up with more reliable (and oppositely directed) results.


**Note** This retrospective study was conducted to determine the proportion of cases in which HEMS may have been useful to patients in an urban trauma system (Santa Clara, California). When the group of patients potentially benefiting from air transport was defined as those with faster transport times, combined with either a need for early operation or hospitalization with ISS at least 9, the authors determined that air transport was beneficial for a maximum of 22.8% of patients. 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. Despite the common-sense appeal of the authors' conclusions, the study is limited by retrospective assignation – over a time period stretching back 11 years – of ground transport times, by a 4-person panel with unclear qualifications for this task (2 surgeons, 1 nurse, and 1 retired paramedic).


**Note** This methodologically rigorous prospective study’s objective was to assess whether the Dutch model of helicopter dispatch to trauma scenes (with subsequent ground transportation to trauma centers) was associated with survival benefit when compared to the traditional mechanism of ground EMS response and transfer. In the overall group (all patient types), the HEMS mortality improvement just failed to reach statistical significance (point estimate for better chance of survival, 2.2, with 95% CI 1.0 to 5.9 and p value 0.076). In the group of blunt trauma patients, the HEMS-associated mortality improvement was statistically significant (OR 2.8, 95% CI 1.1 to 7.5, p = 0.036). For patients with severe head injuries, HEMS was associated with borderline-significant outcome improvement (OR 3.0, 95% CI 0.99 to 8.8, p = .052). Since HEMS responds to the scene and crews provide on-site care, followed in up to 85% of cases by ground transport to trauma centers, one would initially wonder if improved outcome findings applied in other situations. However, the fact that trauma centers were close by (an average of only 13 ground minutes away) means that the time savings accrued by air transport from the scene would have been negligible anyway. Therefore, this study provides good evidence for air medical crew interventions’ mortality impact, leaving the time issues for other investigations (i.e. in areas with longer transport times).

**Note** This statewide trauma registry study’s objective was to evaluate prehospital intubation, not HEMS survival impact. However, the results demonstrating HEMS’ association with improvements in both survival and functional outcome, were relevant to the HEMS debate (as noted in the accompanying editorial to the study which highlighted the fact that HEMS ETI improved outcomes). The mortality and functional outcome benefits from HEMS transport may have been related to airway management or other factors such as transport speed; in a study designed to look at intubation, the mechanism of HEMS’ outcome impact was understandably not elucidated.


**Note** This TRISS-based study assessed outcome for scene-transported trauma patients and found that HEMS reduced mortality by 21.4% as compared with ground transport. There are some oddities to the study’s methodology, and the usual TRISS-related concerns are present. However, the direct comparison of air vs. ground transported patients, and the fact that the multivariate analysis accounted for most (if not all) relevant confounders, strengthen the authors’ findings. Interestingly, though the details of the calculation of HEMS benefit differ from some other TRISS studies, the 20% mortality reduction is firmly in line with results from most of the HEMS literature.


**Note** This retrospective trauma registry-based study assessed outcome for over 15 years of scene-transported head trauma patients and 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 Abbreviated Injury Score (AIS) 3 (OR 1.9, 95% CI 1.2 to 3.0), AIS 4+ (OR 1.7, 95% 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 authors’ conclusions are strengthened by the consistency of HEMS-positive point estimates (most of them statistically significant) for a variety of outcomes in many groups, and the use of elegant multivariate methods (including propensity scoring). The study still doesn’t definitively answer the question of “why” (HEMS improves outcome), but the focus on airway management certainly lays a solid foundation for at least part of the survival improvement being due to ETI skills.


**Note** In a follow-up study to their earlier work assessing peri-ETI physiologic parameters, the UCSD group assessed, among other things, the impact of HEMS vs. ground transport of head-injured patients undergoing scene ETI (mostly by ground ALS). Most relevant to this review was the finding that, in least-squares regression analysis, HEMS as compared to ground transport was found to be significant ($p = 0.011$) predictor of survival. Additionally, in logistic regression HEMS was found to be associated with a significant ($p < .05$) improvement in “good outcome” (discharge to home or rehab/similar facility) with an OR of 0.6 and 95% CI of 0.3 to 1.0. The authors concluded that outcome improvement was most likely due to lower incidence of inadvertent hyperventilation in the HEMS cohort.


**Note** This analysis excluded patients with ISS less than 15, and also excluded patients transported without a physician in attendance. The authors focused on assessing time-to-hospital and transport modality-associated outcome differences. 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, HEMS improved outcomes in TRISS analysis. Although GEMS and HEMS ISS scores were roughly the same, intubation was much more common in HEMS-transported patients (80% vs. 60%). The results were not discussed in sufficient detail to draw many conclusions about the effect magnitude of HEMS versus GEMS, but the paper is useful as a demonstrator of HEMS possible compensation for longer pre-trauma center times by providing outcome-improving interventions such as intubation.

Note This complex analysis used artificial neural network model generation to assess the impact of air transport on outcome of head-injured patients with head Abbreviated Injury Score (AIS) of at least 3. The authors found that, in a number of modeling approaches (including those that were mathematically the best-performing), air medical response to head-injured patients was consistently and significantly associated with improvement in outcome. The outcome benefit was even more concentrated in patients with more critical injuries.


Note This article actually focused on what happens with on-scene times when ground EMS called for HEMS support. The article did not actually set out to address HEMS’ effects on outcomes, but the subject arose in the authors’ methodologically sound assessment of the effects of on-scene time on survival. Not surprisingly, the authors confirmed the long-held notion that prolongation of on-scene times (in patients with significant acuity) increases mortality. The “new” finding with relevance to the HEMS debate, is that the HEMS service deployment to trauma scenes completely negated the mortality cost of longer on-scene times. The authors (trauma surgeons from The Netherlands) concluded that the early intervention of critical interventions from the HEMS crews, allows “golden hour” assessments/procedures to be completed long before trauma center arrival.


Note This study suggests that the simple combination of a time cutoff (30 minutes) with ACS trauma center triage criteria appears to result in high levels of HEMS overtriage. Numerous methodological problems combine to limit the study’s external validity. For example, point estimates for HEMS are positive but nonsignificant. The associated CIs are wide due to a very low number of total endpoints (just 36 deaths). The low number of endpoints calls into question the applicability of regression models with 12 covariates; methodologists prefer no more than one covariate for each 10-15 outcomes. That said, the paper advances a common-sense notion (suggested by pediatric data from the same city) that HEMS overuse is particularly likely within an urban setting.


Note This study focuses on patients with ISS >14 and head AIS >8, with the main outcome of interest survival with neurologically intact or near-intact status. As compared to ground EMS, HEMS was associated with significantly lower overall mortality (21% vs. 25%) and significantly greater survival with no or minor neurological impairment (54% vs. 44%). The authors concluded that, despite the fact that HEMS crews tended to spend more on-scene time than ground EMS transport crews, the reduction in time to advanced care contributed to improved outcome. Furthermore, the authors 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. Rather than simply postulate about prevention of secondary brain injury, the authors actually included data analyses demonstrating better airway and hemodynamic management (e.g. higher blood pressures upon trauma center arrival).


Note One of the largest studies in the HEMS literature (HEMS n 41,987, GEMS n 216,400), this analysis of National Trauma Data Bank (NTDB) data identified a 22% improvement in mortality associated with HEMS as compared to ground transport, for scene trauma patients of all ages/mechanisms (only dead-on-arrival patients were excluded). The study was able to incorporate a broad array of covariates: age, gender, insurance status, mechanism of injury, prehospital times (calculated for HEMS due to straight-line travel and assuming 150 mph transport speed; unavailable for GEMS), Injury Severity Score (ISS), Glasgow Coma Score (GCS), admission systolic blood pressure and respiratory rate, hospital and intensive care unit admission and length-of-stay, mechanical ventilation duration, Emergency Department (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 write 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 pa-
tients in timely fashion, to trauma centers, for logistics reasons when this is necessary. The study reported a last counterargument to "overutilization", that <15% of HEMS patients nationwide, were discharged within 24 hours.


*Note* These authors analyzed the 2007 NTDB data, although the overall n was slightly different from the Brown *et al* study above due to differing methodology (*e.g.* analysis of adults, more stringent inclusion criteria). Multivariate logistic regression adjusting for age, gender, ISS, and RTS identified a 39% reduction in mortality associated with HEMS. Since the data analyzed was a large subset of the same database used in the study published a few months earlier by Brown *et al*, this study’s findings are confirmatory, if unsurprising. The authors of this study used a cutoff for prehospital variable inclusion, of availability of that variable on at least 80% of cases (it appears that 50% was the corresponding cutoff for variable inclusion by Brown *et al*). As compared to the Brown *et al* study, this altered the Sullivent study n and may contribute to the CDC investigators’ finding of more of a mortality benefit than was found by Brown (some have contended missing variables bias studies against HEMS). When analysis focused on adults over 55 the statistical significance of HEMS’ mortality benefit was lost (odds ratio 0.92, 95% CI 0.74-1.13).


*Note* This study used an elegant propensity scoring model to account for multiple confounders in a Cox regression analysis. The study included 10184 trauma scene patients (2717 by HEMS), and assessed 2-week mortality as a function of propensity score (for HEMS transport), ISS, RTS, and transport distance. The methodology included multiple imputation for some missing clinical variables. The data indicated 33% mortality reduction associated with HEMS.


*Note* This study was a secondary analysis of patients who had been enrolled in a hypertonic saline study. Blunt and penetrating trauma patients from 10 ROC sites were assessed with respect to transport mode, for outcomes in TBI and hypovolemic shock cases. There were no differences in mortality or nonmortality outcomes of interest (including neurological functional outcomes) between air and ground transported patients for either patient group. The study has some important limitations as outlined by the authors. There was no adjustment for the critical variable of transport distance, and there was potential for residual confounding by unanalyzed variables such as varying levels of care in prehospital or hospital settings. Other limitations included lack of clustering of analysis on varying centers (with risk of too-narrow confidence intervals). These issues aside, the study findings could potentially be used by either side of the HEMS debate. On the one hand, the finding of “no outcomes difference” will likely be the take-home message of many (such as the discussants providing the commentary accompanying the paper). On the other hand, those who believe HEMS may improve outcome can highlight the fact that HEMS patients, while far more seriously injured, were able to equalize the survival benefit of those travelling from much further away. It’s important to note that the 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 between HEMS and ground EMS patients. The point estimates for survival improvement at 28 days were similar to those identified in the bulk of the HEMS literature: 11% improvement for patients with shock and TBI and 31% improvement in patients with shock only (neither finding significant, and both with wide CIs). There was also a finding that HEMS patients were better resuscitated in the prehospital arena (lower incidence of metabolic acidosis on trauma center arrival). Perhaps the best conclusion is that of the authors themselves, in the closing sentence of the paper: “In the current study, we found no difference in outcome between ground and air transport, suggesting that either approach may be appropriate and that air medical services, implemented in the manner observed in these randomized controlled trials, may overcome limitations of distance and access to specialty care.”


*Note* This study, one of the most methodologically rigorous in the HEMS literature, assessed mortality outcomes in nearly a quarter of a million scene trauma patients with ISS at least 15. Data were used from the 2007-2009 National Trauma Data Bank (NTDB). The methodological rigor of the work stems from employment of multiple approaches to deal with problems of data quality, confounding, and propensity for HEMS use. In sum, every logistic regression model generated for the study demonstrated significant association between HEMS and trauma outcome. The
most conservative estimates for outcomes improvement were found in the propensity-adjusted logistic regression approach: OR of 1.16 for patients treated at Level I centers and 1.15 for patients treated at Level II centers. Put another way, the authors found that one life was saved for each 65 cases transported to Level I centers, the “number needed to transport” for Level II care was 69 lives. Importantly, the authors made a strong case that there were likely other, unmeasured but nonetheless potentially important, HEMS benefits besides mortality. The authors also point out that the data do not address the critical question of triage. The study’s acknowledgment of the current inability to prospectively define which patients will have ISS >15 is quite useful for inclusion in such a major (JAMA) paper; despite the obvious nature of the triage problem it is elided in many discussions of HEMS (over)use.


Note This matching study found odds ratio point estimates for HEMS’ impact on overall survival and TBI of 0.8, but both were accompanied by wide confidence intervals and statistical non-significance. The study had substantial methodologic issues with respect to residual confounding by critical factors such as RTS (significantly lower in HEMS as compared to ground EMS group). In the light of other papers with more rigorous methodology and larger numbers, from the same system in the Netherlands, the contribution of this study to the evidence is uncertain.


Note This analysis of the 2007 NTDB cases with ISS and RTS data available, confirmed the results of other studies demonstrating clear association between HEMS transport and overall improvement in outcomes (OR for overall HEMS effect was 1.78 with 95% 1.65-1.92). The HEMS benefit was identified for all injury severity levels, but subgroup analysis yielded a finding that while HEMS improved outcomes for patients with significant physiologic derangement (RTS less than 6), HEMS worsened outcome for patients who were less physiologically unstable (RTS at least 6). Selection bias and residual confounding seem likely explanations for the inconsistency in physiologic findings as compared to those for anatomic injury, but the common-sense notion that HEMS is most useful for the “sickest” patients is hard to refute.

**ARTICLES FOCUSING ON INTERFACILITY TRAUMA TRANSPORTS**


Note This study has two important strengths: a straightforward if imperfect means of injury stratification and an attempt at explaining improved survival found in HEMS patients. Importantly, the authors point out that there was no time savings associated with HEMS interfacility transport in their series. The relevance of the results to rural settings is appropriately emphasized by the authors.


Note This TRISS study found HEMS improved outcomes when compared to ground transport. Like other HEMS papers from the same period, passage of time may have eroded applicability of the results. For instance, only 8 of the 31 referring hospitals in the study had 24-hour MD (emergency medicine or other-credentialed) coverage in the ED.


Note With their well-designed analysis and cogent discussion, these authors found a significant HEMS benefit after covering nearly all of the bases (there was potential for residual confounding due to referring hospital care). The barriers to performance of the "natural experiment" research project were effectively handled, and the discussion includes detailed handling of potential study flaws.


Note This group of burn surgeons determined that HEMS likely benefits some, but the resource is overutilized. The authors’ approach of discussing with local ground EMS providers, the real reasons for HEMS triage (e.g. ability to pay or need to preserve local ground EMS availability) represents an important contribution to the triage literature.

**Note** One of the largest ground-versus-air transport comparisons in the interfacility trauma literature (HEMS *n* 14,771, GEMS *n* 60,008), this analysis of National Trauma Data Bank (NTDB) data followed the same general lines as the above-described scene trauma study by the same authors (published a few months earlier). The authors’ overall multivariate analysis incorporated the myriad covariates described above for the scene run paper. Multivariate regression reported was as negative for demonstrating HEMS survival benefit; the point estimate of 6% improvement in OR (point estimate 1.06) was associated with a 95% CI that just crossed the null value (0.99 to 1.13, *p* = .07). The authors executed an *a priori*-planned subgroup analysis on those patients with ISS below, and those with ISS above, a cutoff of 15. For those patients with lower ISS, HEMS was (unsurprisingly) associated with no survival benefit (OR point estimate and 95% CI: 1.06, 0.92 to 1.24, *p* = 0.42). For patients with more serious injury—which group constituted 49% of all HEMS transports—there was a significant mortality improvement associated with air medical transport (OR 1.09, 95% CI 1.02 to 1.17, *p* = .01). HEMS patients were far more severely injured (e.g. intra- and early post-transport deaths 10x higher), and required substantially more resources (e.g. 50% more likely to need emergency operation), than those transported by ground EMS. The study’s broad array of covariates and the clear demonstration of improved outcome in a group (those with ISS >15) comprising half of the air transported cohort, adds to the strength of the study message. The study authors pointed out additional interesting facts addressing logistics and utilization (e.g. only 8% of HEMS patients were discharged within 24 hours). Among the study weaknesses acknowledged by the authors was the failure to account for possible morbidity improvements that could benefit patients with lesser injury acuity.

**ARTICLES INCLUDING A MIX OF SCENE + INTERFACILITY TRAUMA TRANSPORTS**


**Note** In this study, the authors found that 11 lives were saved for each 1000 HEMS transports. The study did not rigorously adjust for all potentially important factors (e.g. ALS vs. BLS care, scene vs. interfacility mission type) but given the direct comparison between air and ground transport and the large study numbers, the data seem to substantiate the authors’ conclusion that, while improved triage is desirable, HEMS use saves lives in pediatric patients.


**Note** One of the relatively few large-scale (*n* = 16999) studies which did not employ TRISS, this study used a logistic regression model and adjusted for ISS, prehospital level of care (ALS vs. BLS), transport type (i.e. scene vs. interfacility), and demographics. The authors found that HEMS transport was associated with a 24% reduction in mortality.


**Note** This paper attempted to address two variables at once: transport by air vs. ground and transport to regional hospitals vs. the German equivalent of Level I centers. The authors found that, for patients transported directly to trauma centers, there was no mortality improvement associated with HEMS vs. ground ambulance use. For patients who presumably were too far away for primary ground transport to the Level I centers, HEMS transport directly to Level I hospitals was associated with significantly better survival (a 19% mortality reduction) when compared to patients who were initially transported by ground to local hospitals and subsequently transported for Level I care.


**Note** This study compared two means of getting pediatric trauma patients to the tertiary care center by air. Patients transported directly to Level I care from the scene, by helicopter, were compared with those who were transported by ground to regional hospitals and then transferred (by air, in the vast majority of cases). The authors found no benefit to immediate HEMS transport from scenes, and argued HEMS should be used for secondary transport after stabilization at referring hospitals. The authors acknowledged likelihood of residual confounding by severity since groups were distinctly different (e.g. scene transports were more likely MVC trauma and pedestrians struck). TRISS analysis found that scene HEMS transport saved an additional life for every 200 transports (*W* statistic of .5 for scene HEMS, as compared with 4.5 for ground-then-air interfacility transport, no *p* value calculated).

5. Mitchell AD, Tallon JM, Sealy B. Air versus ground transport of major trauma patients to a tertiary trauma centre: A

**Note** This population-based study covered an entire (rural maritime) province of Canada. The use of HEMS for adult blunt trauma (for patients with ISS >11) was found to improve mortality by 35% as compared with ground EMS. The difference in TRISS-derived W for ground and air transport was 8.8 for patients with ISS >11; in this subgroup HEMS use saved 88 lives for every 1000 transports. The study is particularly strong, given its lack of selection bias (every trauma patient transferred to tertiary care in the province was captured) and straightforward methodology.


**Note** In a natural experiment paper covering a relatively discrete population (Long Island), the authors performed an elegant analysis of trauma patient care and outcomes before and after addition of HEMS. The authors’ trauma system already included use of one helicopter, but it was frequently impractical for that aircraft to reach the study service area and a second HEMS unit was added to provide new coverage for eastern Long Island (New York). While the authors’ methodology and discussion included many details with focused relevance to their geography, the primary findings of this 10-year study can be summarized by changes that occurred in the pre-HEMS vs. HEMS era. The main result was overall mortality, which decreased significantly in the HEMS era (16.2% down to 11.9%, p = .02; the relative percentage mortality reduction of 26.5% is quite consistent with many other studies in the HEMS literature). Additionally, 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, interfactivity HEMS transports from the community hospitals remained stable (i.e. there was no increase in HEMS utilization for interfactivity transport; the increased utilization was for scene flights). The overall acuity (as measured by ISS) was no different for the HEMS period. Severely injured patients (defined by ISS >15) were significantly more likely to undergo HEMS transport in the HEMS period.


**Note** In this registry- and provincwide database study, adult trauma patients were split into 3 groups: *Group 1* consisted of adult trauma patients transported to a tertiary care trauma center by air transport. *Group 2* patients were those triaged to HEMS (i.e. accepted by the online Medical Control Physician for air transport), but transported by ground due to aviation issues. *Group 3* included “all other” adult trauma patients transported by ground ambulance. The natural experiment was demonstrated “successful” by the fact that there was no statistically significant 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*. *Group 1* patients had a proportion of scene calls (20%) that was higher than that of *Group 2* (7%); *Group 3* patients were mostly (58%) scene transports which was related in part to their being more urban in nature. As compared to *Group 2* patients (whose mortality was equal to TRISS-predicted), *Group 1* status was associated with statistically 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). This study, one of the more compelling in the HEMS literature, is a population-based approach whose natural experiment design appears to have been successful in approximating (to some extent) an RCT. The fact that HEMS’ W in this study is so close to those of other studies in the HEMS literature underscores the likely accuracy of a general estimate for trauma W of 5.

- **Cardiac**

**Note** This study went far towards demonstrating the safety – at least for bleeding complications – of HEMS transport of patients after thrombolyis administration.


**Note** These authors found that interhospital transport was feasible and safe, even for unstable patients. The paper makes the argument that streamlining of interfactivity transport operations can significantly extend the coverage area of primary angioplasty.

Note Though most of the patients in this “Air PAMI” trial actually traveled by ground, this study began to make the case—becoming stronger over time—for use of HEMS as a component of early transport of patients for primary percutaneous coronary intervention. The study’s results were truly surprising in that the transported group had a 6-fold improvement in composite outcomes, despite the transported cohort’s having triple the time to definitive therapy (155 vs. 51 minutes).


Note This study used a “before-and-after” approach to examine endpoints of time savings and health outcomes associated with institution of a new triage and HEMS transfer system designed to expedite community hospital evaluation and referral of STEMI patients to a PCI center. Protocol changes effected midway through the study included: 1) community hospital STEMI care changes emphasizing time savings (e.g. elimination of heparin and nitroglycerin infusions), 2) simultaneous PCI lab and HEMS activation from a single call to the receiving center, and 3) bypass of the receiving center’s ED after HEMS transport. For the main endpoint (community hospital presentation to wire-crossing time), the “after” period was associated with significantly shorter times (105 vs. 205 minutes, \( p = 0.0001 \)). Time savings were achieved by faster HEMS dispatch (from 35 to 16 minutes, \( p = 0.0004 \)), streamlining time intervals between HEMS dispatch and PCI center arrival (from 56 to 45 minutes, \( p = 0.002 \)), and other interventions such as bypassing the receiving center ED. The proportion of patients with door to wire-crossing times under 90 minutes increased from 0% to 24% (\( p = 0.0001 \)), and the percentage with door to wire-crossing times under 120 minutes also increased (from 2% to 67%, \( p = 0.0001 \)). There were no significant differences between the before and after periods, with regard to the following patient outcomes: death (\( p = .28 \)), urgent revascularization (\( p = .62 \)) or hospital length of stay (\( p = .46 \)). The lack of health outcomes advantages were acknowledged by the authors, who appropriately point out that the substantial time savings represent a significant finding in their own right (given the widespread acceptance of the importance of time-based outcomes assessment in STEMI care).

**NEONATAL**


Note The authors basically performed a descriptive analysis of HEMS (and ground) neonatal transfers, and concluded that HEMS was a critical part of a regionalized neonatal critical care network. While the paper clearly suffers from suboptimal ability to focus on the particular contribution of HEMS, the paper is important because of the contention of the authors that its results show HEMS to be a vital part of a region’s neonatal care and transport system.


Note The authors of this study reported a large-scale, population-based (basically descriptive) analysis of 256 neonatal transports in central Norway. The study found that mortality of this transported cohort was similar to that of neonatal outcomes of nontransported patients (in Norway). The results included findings of occasional performance of life-saving interventions. The authors also found that, as compared to the pre-transport time frame, there were improvements in oxygenation, ventilation, and circulation during the transport phase.


Note This “safety study” determined there was no difference between air or ground transport (by the same team, into Miami Children’s Hospital) and intra-transport need for cardiopulmonary interventions; there was also no difference in risk of intratransport development of hypocapnia or hypercapnia.

**NEUROLOGY/NEUROSURGERY**


Note This was primarily a “safety study,” demonstrating that HEMS transport of post-lysis stroke patients did not result in worsened outcome.

Note The authors of this paper noted that since stroke patients tend to require relatively little pretransport “packaging,” speed benefits of HEMS transport may be well suited to expedited transfer of such patients to stroke centers where emerging therapies are becoming increasingly utilized.


Note This study addressed the contribution of HEMS to facilitating of patient transport from rural “scenes” to a stroke center. HEMS was called to the scene for patients with suspected stroke, and the diagnosis was usually correct (stroke was ultimately diagnosed at the receiving center in 76% of cases). During the study period, stroke transports comprised 4% of the HEMS service volume, but HEMS-transported stroke patients accounted for nearly a fourth (23%) of all patients receiving thrombolytic therapy at the receiving center. If one accepts the premise that early thrombolysis is of benefit, then this paper adds to the previous early investigations which begin to address whether HEMS should have a role in acute stroke care; the authors demonstrated that a stroke triage protocol based on the trauma model resulted in widening of a stroke center’s coverage area. The authors’ cogent discussion makes the point that it is a little early to attempt rigid cost-benefit analysis, but that if the short- and long-term benefits of stroke lysis are achieved with HEMS transport, the extra cost of air transport is worthwhile.


Note This retrospective review assessed trauma, cerebrovascular, tumor, and other neurosurgical HEMS interfacility transports into a single center (MGH in Boston). The authors retrospectively calculated ground transport times using GoogleMaps, and were unable to account for any traffic or weather issues leading to HEMS use. The study, which lacked any ground comparison group, also discounted any possible HEMS outcomes contribution other than that accrued by time savings. Based upon findings such as lack of surgical intervention in 1/3 of the study cohort, the authors concluded that HEMS was often inappropriately used. Review of the study’s results actually demonstrates a level of HEMS overtriage that is quite consistent with widely accepted levels. The transport cohort was extremely high-acuity, and the study authors’ expectations of referring ED physicians to perform high-level neurosurgical triage decision-making may be impractical.

5. Olson MD, Rabinstein AA. Does HEMS transfer offer benefit to patients with stroke? *Stroke* 2012; in print.

Note Air transfer of patients in this study got to the stroke center a statistically significant 15 minutes earlier than those transported by ground, but in this post-lysis group there was questionable clinical significance to that time savings. The overall outcomes were similar between the two groups. The study was not randomized, and the geographic disparities of the air and ground groups were not fully explored. These shortcomings and some others (as discussed by the authors) aside, there is common sense in the notion that once time-windowed therapy has been administered, HEMS decision making is different from that which occurs in the pre-treatment situation.


Note This study’s primary endpoint was the administration of thrombolytic therapy. The “timing” surrogate endpoint was used to demonstrate the capability of HEMS to enable patients to arrive at stroke centers in time to receive this time-windowed therapy. The authors found that both scene and interfacility HEMS transport allowed for higher thrombolysis rates, and that scene HEMS response was associated with the highest chances of stroke patients’ receiving thrombolytics within 90 minutes of symptom onset.

- **OBSTETRIC**


Note This study, which has its theoretical underpinning in the concept that antenatal (as compared with postnatal) transport patients results in improved outcomes, makes a strong case for importance of air transport of obstetric patients. The authors found that HEMS saved time (especially when there was traffic congestion), and that neonatal outcome for transported patients was similar to that for nontransported patients at the same center. Additionally, use of HEMS allowed for increased chances of delivery at tertiary maternal-fetal medicine centers: 25 patients (of 100 studied) would have been kept for delivery at community hospitals if HEMS were not available (due to re-
ferring physicians’ refusal to place these patients on ground ambulances).

   
   **Note** The primary utility of this study was as a “safety study” demonstrating HEMS obstetrics transport was not associated with significant outcomes detriment. The authors state that their study provides support for the view held “by most investigators” (as they state) that maternal/fetal risks associated with HEMS transport are “at most, minimal.”

   
   **Note** These Japanese authors point out that their country has limited tertiary care facilities for maternal/fetal medicine, and that maternal (prenatal) transport by air is an important part of providing regionalized care. The authors assessed 26 HEMS transfers of pregnant women to their institution; in 21 cases the baby was delivered and in the others the pregnancy was stabilized. Using actual air transport times, and estimated ground transport times, the authors calculated that HEMS use was associated with savings of 101 minutes’ out-of-hospital time (median flight time, 24 minutes; median estimated ground transport time, 125 minutes).

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**VASCULAR**

   
   **Note** The primary utility of this paper is that it introduced the concept of “direct-to-OR” transport of nontrauma. Such expedited care, though difficult to assess statistically, seems likely to improve patient outcome in some instances.

   
   **Note** This paper confirmed the feasibility, and probable utility, of HEMS crews’ bypassing receiving hospital EDs in order to bring patients directly into the operating room. Given the prevalence of CT scans at referring hospitals, the 100% accuracy in correctly identifying patients with ruptured AAA constitutes a major reason for the success of the direct-to-OR protocol.
SECTION V. POSSIBLE HEMS BENEFITS TO PATIENTS

The question of HEMS benefits to patients, particularly with respect to prospectively identifying those likely to benefit, remains controversial. However, as revealed by a perusal of literature outlined above, there is sufficient information to allow for discussion of outcomes improvement. In this section, mortality and nonmortality endpoints will be addressed, with attention also given to other benefits that could reasonably be inferred.

A. Mortality improvement as an endpoint
1. **Overview**  This seems like the most obvious potential benefit upon which to focus, and in fact survival improvement has been the main endpoint of most of the major HEMS studies.
2. **Strengths**  Mortality is a relatively concrete endpoint (the only vagaries being introduced by a post-incident time demarcation, such as 30- or 60-day mortality as compared to mortality during the index hospitalization). Mortality is also relatively easy to address in the large, retrospective study designs (usually registry-based) that comprise much of the HEMS outcomes literature.  \(^{6,74,75}\)
3. **Weaknesses**  Mortality can be defined differently and somewhat arbitrarily in terms of time frames; 30- or 60-day mortality is a common endpoint but one of the most methodologically rigorous studies in the HEMS literature demonstrated 33% improvement in mortality as occurring during the initial 2 weeks post-incident. \(^{76}\) Additionally, though mortality is undoubtedly the most important clinical endpoint, it is difficult to assess unless there are large patient numbers and some means of matching acuity in air and ground transported patients. Finally, most HEMS study designs performing isolated assessment of mortality do not isolate the HEMS benefit mechanism (e.g. streamlined prehospital times, improved airway management).
4. **Conclusion**  Most of the HEMS literature emphasizes the mortality endpoint. While the quality of evidence is debatable, systematic assessment of HEMS’ impact will need to incorporate consideration of mortality.

B. Morbidity improvement as an endpoint
1. **Overview**  If mortality assessment is limited by inherent methodological challenges, it makes sense to ascertain whether any nonmortality endpoints are affected by transport mode.
2. **Strengths**  Even if HEMS does impact mortality, it likely does so at a sufficiently low frequency that detection can be difficult (given methodological issues and need to control for acuity). It is possible that nonmortality endpoints are reached with greater frequency than survival improvement, and thus nonmortality endpoints may be easier to detect. Additionally, nonmortality endpoints may provide clues to the mechanism by which HEMS improves survival (e.g. decrease in aspiration pneumonia implying improved airway management).
3. **Weaknesses**  Morbidity improvement is a heterogeneous endpoint. Depending on disease process, a myriad of nonmortality endpoints could theoretically be assessed. The potential utility of the “strength in numbers” argument (i.e. that nonmortality endpoints occur more frequently than survival accrual) is somewhat offset by the fact that assessment of many nonmortality endpoints requires analysis of a subgroup of patients in a certain diagnostic category; such limitation of the focus of a study results in lower numbers of patients with the endpoint in question. (Sometimes there are still enough numbers for functional outcomes assessment. For head injuries there is evidence that HEMS improves these nonmortality outcomes, \(^{6,77}\) although some question remains. \(^{78}\))
4. **Conclusion**  The literature review above includes studies addressing nonmortality endpoints such as quality-of-life and Glasgow neurological outcome score, but the fact remains that despite attractiveness of nonmortality endpoint assessment, methodological hurdles have prevented their widespread use. It is fair to point out that those considering the weight of the evidence in favor of HEMS’ improvement of trauma mortality, have also stated the naturally following conclusion that if HEMS improves mortality, there are likely considerable nonmortality outcome gains as well. \(^{79-81}\)

C. Secondary endpoints
Secondary endpoints are myriad; the most useful are those with high clinical relevance. Examples of potentially important secondary endpoints include:

1. **Physiologic endpoints (e.g. associated with airway management)**  As mentioned earlier in this discussion, HEMS airway management for head injured patients has been shown to be associated with improved patient outcome. \(^{6,82}\) Investigators have addressed the mechanism for outcome improvement. It appears to be related to improved oxygenation and ventilatory practices, as reflected in peri-ETI (i.e. before and after intubation) physiologic parameters such as end-tidal CO\(_2\). Peri-ETI physiology seems to be
frequently disrupted during ground EMS ETI, but not nearly so much during HEMS ETI or even with HEMS transport post-ground EMS ETI. Evidence demonstrating deleterious impact of peri-ETI physiologic disruptions (in head injury patients, at least) is sufficiently compelling that studies showing markedly lesser derangement in HEMS patients, should be considered as highly relevant to the outcomes debate. Recent analyses also demonstrate improved hemodynamic management, with investigators concluding that improved blood pressure management by HEMS was partially responsible for improved head injury outcome.

2. **Pain control**

   After being neglected for too long as a priority for acute-care (and prehospital) medicine, the subject of pain care is receiving its due. Experts in prehospital care have written that pain care is a valid endpoint in and of itself. Whether due to protocol restrictions on ground EMS or other factors, HEMS providers tend to be far more diligent than ground ambulance providers in assessing and treating pain.

   While HEMS patients are different from ground EMS patients, the studies of patients with suspected isolated fractures result in substantial differences in analgesia rates (1.8–12.5% for ground EMS, to >90% for HEMS as outlined elsewhere). In fact, EMS experts writing about pain management have acknowledged the better HEMS performance with respect to analgesia provision, stating that (as compared with ground EMS) HEMS is characterized by a “population of patients and providers very different from ground EMS-transported patients.”

   As HEMS researchers try and extend their outcomes assessments beyond mortality, pain care represents a fertile ground for (partial) justification for use of HEMS. In some patient populations, such as those with suspected myocardial infarction, pain control is a paramount clinical goal. Thus, assessment of potential benefits of HEMS should take into account studies finding better pain control in HEMS-transported cardiac patients – who are of higher acuity with commensurate increased likelihood of refractory pain – than those transported by ground. It is easy to argue that good pain care can be brought to bear by ground EMS (i.e. analgesia is allowed in protocols), but the existing evidence on what is done, is consistent with a HEMS pain management benefit.

D. **Surrogate endpoints**

   Distinction between endpoints that are secondary (as outlined above) and those that are surrogate (defined in this discussion as indirect mediators of improved outcome) can be tricky. Examples of surrogate endpoints include:

1. **Earlier arrival of ALS**

   Especially in rural or isolated areas, HEMS may represent the best means to get ALS to patients within a reasonable time frame. The significant improvement in “time to treatment” associated with HEMS utilization has been noted in systems throughout the world. Though there are few data to actually prove that ALS improves outcomes, many EMS experts – and most systems benchmarkers – believe this to be an important goal for optimizing care of many types of patients. Furthermore, given the extant data showing that at least one ALS intervention – ETI – improves outcome when provided by HEMS, it naturally follows that the earlier provision of such intervention will often be in the patient’s best interests. More recent data, especially focusing on patients with severe trauma including head injuries, suggests that the earlier arrival of those capable of providing ALS-level airway and hemodynamic support translates into improved overall outcome and better neurological function. Authors of case series demonstrating high rates of neurologically intact survival in diagnoses such as drowning, also make strong arguments for the advantages of dispatching experienced ALS-level crews to areas in which ALS ground EMS coverage is lacking. Trauma specialists commenting on nationwide data indicating outcome improvement with HEMS have written that although HEMS’ logistics advantages may be uncommon in some areas, there are definitely regions within the U.S. in which the access provided by HEMS is life-saving.

2. **Extended scope-of-practice prehospital care and critical care experience/capabilities**

   In many regions, HEMS providers have pharmacological and procedural capabilities that outstrip those of ground EMS. The differences in care scope can be dramatic. A report from the U.K. contended that patient outcomes were improved by performance of field thoracotomies. Trauma surgeons reinforcing the concept of providing critical interventions during the “golden hour” have written that HEMS response to trauma scenes allows for provision of this life-saving care in timely fashion. Analysis of U.S. data from the National Trauma Data Bank (NTDB) prompted one group of authors to conclude that, on a nationwide level, one of the major advantages of HEMS is the higher level of care often provided by air medical crews. A later study of the NTDB data, finding that HEMS’ overall survival benefit (OR 1.78, 95% CI 1.65-1.92) seemed to be independent of prehospital time, also led to authors’ and discussants’ positing that crew expertise rather than time was the major
mediator of air transport benefit.\textsuperscript{92}

The situation in the area served by Mayo Clinic in Minnesota may be typical. Ground EMS providers carry 20 different drugs but HEMS crews carry three times that number and can provide therapy such as blood transfusion and antibiotics for patients with open fractures.\textsuperscript{4} In other HEMS programs, prehospital providers can provide advanced interventions such as tube thoracostomy. In fact, available evidence suggests that HEMS crew-placed chest tubes (by EM residents) are as effective as, and no more likely to be associated with complications than, those placed in the hospital setting.\textsuperscript{93}

Especially in rural areas, the only prehospital care available may be BLS level.\textsuperscript{4} It has been noted that since “HEMS brings a level of care to a trauma scene or small referring hospital that is over and above care rendered by an ALS ground ambulance,” many procedures such as intubation (even for patients transferred from referring hospitals) are deferred to the HEMS crew.\textsuperscript{4} Thus, HEMS is an important mechanism to get scene and interfacility patients medical crews with needed expertise. Airway management is a key offering of HEMS. Flight crews using neuromuscular blockade have long demonstrated ETI success rates that rival those achieved in the E.D., whereas outcomes with ground EMS ETI (even with neuromuscular blockade) tend to be worsened.\textsuperscript{4,6,18,67,92,94-96} It seems likely that poor results from ground ETI are related in part to provider inexperience and differences in training for ground and air EMS personnel.\textsuperscript{4,6,97,98} As another example, critical care transport teams (that use both helicopter and ground vehicles) have reported sophisticated mechanical ventilator management enabled by application of ETCO\textsubscript{2} monitoring in pediatric and adult patients.\textsuperscript{4,83,99}

As mentioned previously, there is increasing evidence that better airway management skills are responsible for better outcomes in at least some patient groups. While this HEMS discussion is not the place for a detailed analysis of airway management issues, it is undoubtedly the case that failure to obtain or maintain a trauma patient’s airway is a significant cause of preventable death.\textsuperscript{100}

For patients with head injury, there are large-scale studies identifying markedly improved outcome for HEMS patients, as compared to ground ambulance transports, for those undergoing prehospital ETI.\textsuperscript{4,6,77,82} Technically, ETI is better considered as an “ALS” level intervention, rather than an expanded practice-scope maneuver. However, it is unrealistic to expect that the airway management expertise possessed by HEMS providers can be easily attained by practitioners with less experience and less rigorous training.\textsuperscript{97} (What only the future can tell, is whether HEMS crews will maintain their proficiency and high ETI success rates. There are few data, but anecdotal evidence suggests the possibility of skills dilution due to burgeoning numbers of air transport services and increasing difficulties in obtaining ETI experience in settings such as the operating room.)

The improved outcomes for head-injury patients transported by HEMS have also been suggested to be associated with other traditional ALS-level maneuvers that are simply performed better by highly trained air medical crews. In a discussion of possible explanations for HEMS-associated improved mortality and neurologic outcomes for HEMS (compared to ground ALS), an Italian group\textsuperscript{77} noted that not only were airways more commonly managed, but IV access and fluid resuscitation were handled significantly better by HEMS. Austrians have reported HEMS improves outcomes due in part to better performance of ALS skills such as intravenous access, fluid resuscitation, airway management, and chest decompression.\textsuperscript{101} A German study also suggested that increased likelihood of pre-trauma center intubation (80\% HEMS versus 60\% in similar-acuity ground patients) contributed to improved outcomes despite longer pre-trauma center times in the air-transport cohort.\textsuperscript{102}

In addition to ETI capabilities, HEMS crews operate with benefit of experience in dealing with critically ill and injured patients. HEMS crews may in fact have more comfort with high-acuity patients than rural hospital physicians.\textsuperscript{4,100}

Analyses of HEMS systems have consistently revealed a relationship between crews’ advanced training/experience and performance of critical tasks. In this era of focus on medical errors, it is noteworthy that recent studies (particularly in the pediatric population, but also in adults) have strongly suggested that errors (e.g., missed esophageal intubations, inadvertent extubation, incorrectly sized or too-deeply placed endotracheal tubes) are more likely in ground as compared to HEMS-transported patients.\textsuperscript{103} There has been little concrete correlation between such findings and mortality, but the common-sense implications of minimizing patient-care errors are difficult to refute.

3. \textit{Streamlined prehospital times for scene missions}

It is well known that, particularly for rural locations, prolonged EMS response/transport time results in increased trauma mortality.\textsuperscript{104} Shorter transport duration would seemingly be a “given” for HEMS use, but since early studies (e.g., Baxt \textit{et al})\textsuperscript{47} found that HEMS didn’t save time, this supposed HEMS benefit has been unclear. Studies from regions as disparate as California and the Netherlands clearly demonstrate HEMS mortality benefit
while finding similar scene-to-trauma center times for ground and air transports. \textsuperscript{105,106}

One study from the Netherlands finds that (physician-staffed) HEMS crews’ scene times are 10 minutes longer than those for ground EMS crews (25 vs. 35 minutes in a system in which HEMS crews stabilize patients prior to ground transport to Level I care).\textsuperscript{60} Scene time prolongation was accounted for by acuity and casemix, and adjusted analysis showed no effect of on-scene time on survival (OR 1.0, p = .89).\textsuperscript{30} In fact, the traumatologists assessing the slight prolongation in on-scene times associated with HEMS argue that bringing advanced interventions to the scene was actually a benefit to survival – the HEMS crews’ interventions had sufficient salutary impact as to completely negate the well-known adverse outcome impact of prolonged prehospital times.\textsuperscript{100}

The consideration of urban scene HEMS use is problematic. On the one hand, HEMS transport from areas close to a trauma center doesn’t make much sense as a time-saver when distance is considered. On the other hand, such areas tend to be particularly prone to traffic congestion and transport delays. Since most studies focusing on transport times have the times for one vehicle type or the other “estimated” it is easy for bias to be introduced. The fact that such transport times for either air or ground EMS are estimated retrospectively (i.e. lacking information about traffic or weather or other conditions) further dilutes the value of these estimates.

Faster transport time is, in some cases, potentially life-saving – the premise that faster transport occasionally improves trauma mortality is widely accepted. Authors focusing on logistics support the notion that time to definitive care is an appropriate primary endpoint, writing “The correlation between length of time to definitive care and outcome has been well established in the literature, so the premise that faster transport is better seems justifiable.”\textsuperscript{107}

The authors of a Pennsylvania trauma registry-based head injury study, in noting that HEMS was associated with improved survival and functional outcome, noted that that their results could have “simply reflected the effect of [faster] transport time to trauma center.”\textsuperscript{6} Furthermore, the impact of logistics on trauma mortality has been argued in a JAMA study which found that HEMS represented the only mechanism by which 27% of the U.S. population had timely Level 1 or 2 trauma center access (within an hour of receipt of emergency call).\textsuperscript{108} Put another way, HEMS has been estimated to be the only mechanism by which 81.4 million Americans have timely (<1 hour) access to Level 1 or Level 2 trauma centers.\textsuperscript{108} The authors concluded that new helipad placements and additional HEMS programs “could be an important, and practical, means of extending trauma center access to populations that currently have none.” Since the JAMA study group comprised both clinical and epidemiologic trauma systems leaders, their paper – with its assumption that HEMS is useful from a time-distance perspective – is a useful complement to the HEMS utility dialogue. The fact that HEMS provides the only timely access to high-level trauma care is particularly noteworthy, given recent large-scale studies finding that Level I trauma care results in a distinct outcomes benefit as compared to other levels of trauma care,\textsuperscript{109,110} for at least a quarter of the US population, helicopters thus represent the only mechanism for rapidly accessing life-saving care for injuries. Recent data indicating the growing numbers of trauma center closures, serve to emphasize the importance of HEMS as a mechanism to get patients to a diminishing number of trauma centers.\textsuperscript{111}

Related conclusions about the critical utility of air medical transport for the U.S. population have emanated from burn investigators. While there is no “golden hour” for burn patients, epidemiologists and clinicians writing in JAMA point out that early care (in the first few hours) at a burn center improves outcome, and that HEMS is the sole mechanism by which millions of Americans have access to burn center care within 2 hours of injury.\textsuperscript{112}

A case series from the Austrian Stroke Registry reported time-related benefit to primary HEMS transport for stroke patients. The study reported that patients who were scene-transported for stroke, were the most likely (as compared to ground scene or ground/air interfacility), to receive thrombolytic therapy within 90 minutes of stroke symptom onset.\textsuperscript{113}

4. **Rapid transport for interfacility missions**

The idea of HEMS utilization to expedite care for patients with time-critical injury and illness is not new. There is a significant body of literature addressed in this monograph and elsewhere, that demonstrates HEMS utility for time savings (and mortality advantage) in secondary (interfacility) trauma transport.\textsuperscript{114} Loss of HEMS availability has been recognized as a potentially important factor causing increased trauma mortality in patients presenting to non-Level I centers.\textsuperscript{115}

Besides use for trauma diagnoses, there is growing emphasis on employment of HEMS to expedite care for patients with time-critical non-trauma illness. The utility of HEMS’ logistics/speed capabilities to extend the reach of Level I centers’ time-windowed advanced cardiac and stroke care has been the subject of increasing attention, with particular emphasis being given on the ability of HEMS to expedite care of these time-sensitive diagnoses.\textsuperscript{116,117} The use of air medical resources to rapidly move patients to specialized centers is gaining increas-
ing attention in part because of the ever-growing realization that “time is myocardium”, “time is brain tissue”, etc.\textsuperscript{116,118-120} To some degree, the increasing complexity of many aspects of medical and surgical care are translating into strong arguments for centralized provision of advanced interventions. Whether the case is cardiac, trauma, stroke, or even ruptured abdominal aortic aneurysm,\textsuperscript{121} there are solid grounds for belief that vital outcomes are improved by getting patients rapidly to centralized centers.

Related to the trauma findings, is the fact that systems’ access to certain surgical subspecialties such as neurosurgery, is a major problem. One 2011 study\textsuperscript{120} from Boston, by a group of neurosurgeons assessing a broad variety of transports to their service (trauma, cancer, cerebrovascular, and other patients), demonstrates the ability of HEMS to extend neurosurgical care. Patients in a cohort of 167 ED-transferred HEMS patients over a year, had both high acuity and frequent operative intervention (needed in 2/3 of cases).

In terms of cardiac patient transports and time savings, there is increasing emphasis on getting patients with myocardial infarction to primary PCI as the treatment of choice if a 90-minute first-door-to-balloon time can be met; expedited prehospital care – including HEMS – will play an important role in cardiac care systems.\textsuperscript{122,123} In fact, the 90-minute “window” is not absolute. Emergency Medicine experts have written that the maximal benefit of primary PCI is accrued in the initial 60 minutes.\textsuperscript{124} It is known that each 15-minute decrement in time to PCI, from 150 minutes down to <90 minutes, is associated with 6.3 fewer deaths per 1000 patients treated.\textsuperscript{125} Data from 2009 suggest that the inflection points of the time savings and mortality benefit curve, are somewhere around 45 and 225 minutes; this means that time savings is associated with mortality benefit when patients get to PCI within 45 to 225 minutes of initial “door” time.\textsuperscript{126}

The numbers for cardiac interfacility transport efficiency improvements lead to convincing arguments in favor of appropriate HEMS use. In Pennsylvania, for instance, investigators instituted a streamlined HEMS transport program for community hospitals to get patients into receiving center PCI, and tracked the proportions of patients with community hospital door to wire-crossing times under 90 minutes 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{117} Complementary to the Pennsylvania results are Ohio data demonstrating that use of HEMS transport for cardiac patients is no guarantee of arrival to cath labs within recommended time frames.\textsuperscript{127} HEMS is potentially important as a part of a cardiac care system, but the air medical resource must be used wisely.

Cardiac patients are not the only nontrauma diagnosis for which time is critical. Each hour of ischemic stroke results in neuronal damage approximating 3.6 years of normal aging.\textsuperscript{119} The Austrian Stroke Registry analysis of likelihood of receiving thrombolysis (an endpoint as well as a surrogate for time) found significantly higher rates in HEMS interfacility-transported stroke patients as compared to those who came by ground.\textsuperscript{113} Furthermore, ED specialists have noted with concern the consistency of reports finding nearly 1 in 5 patients receiving lysis for “stroke” based upon CT reading, in fact have non-stroke “mimics” of acute thrombo-embolic CVA.\textsuperscript{128}

The increasing awareness that advanced imaging optimizes accuracy and safety, combined with the current (and likely near-future) lack of round-the-clock availability of such imaging,\textsuperscript{129} has high potential to translate into a major role for early and rapid HEMS transport for stroke. These time-critical findings emphasize the importance of integrating HEMS into stroke care networks. Addition of air medical resources into logistics calculations halves the numbers of Americans who lack timely (within one hour) access to a primary stroke center (from 136 million to 63 million).\textsuperscript{129} Integration of HEMS into stroke networks has been shown to have salutary impact on thrombolysis rates (i.e. getting patients to stroke centers in time for lysis).\textsuperscript{113}

Sepsis, a long-recognized disease process, has not historically been considered “time-critical” but this view is changing with the advent of studies demonstrating improved outcome from early goal-directed therapy. Recent reviews of sepsis care emphasize the importance of the six-hour goal for institution of high-level sepsis care.\textsuperscript{130} Though many patients with sepsis do not undergo transport at all, HEMS may in some cases provide a useful mechanism for rapidly getting patients to appropriate, time-critical, goal-directed therapy.

HEMS has also long been known to allow for maternal/fetal outcome benefits for high-risk obstetrics transports that would not have occurred (due to physician unwillingness to have prolonged transport times) in the absence of air transport.\textsuperscript{51} Similarly, a group from Florida\textsuperscript{57} has reported that scene transports for suspected stroke patients resulted in extension of their stroke care to patients previously outside of the “logistics envelope”, and others have reported that HEMS is useful to expedite interfacility stroke and cardiac transports.\textsuperscript{131,132}

One approach from Boston incorporates prehospital EKG triggering of both HEMS dispatch and activation of the receiving hospital’s cardiac cath lab. The aircraft thus arrives at the (non-PCI-capable) community hospital within minutes of the patient’s arrival by ground EMS.54 After the community hospital s ED physician quickly confirms the diagnosis based upon review of the prehospital 12-lead EKG, the tertiary center’s cardiac catheteriza-
tion laboratory activation is confirmed and the helicopter (either already at, or very close to, the community hospital) completes rapid transport directly to the cath lab. Initial experience with this protocol has found it saves about 10-20 minutes. Such a time savings initially appears modest. In fact, it is at least as much time has been saved by other prehospital and hospital practices – associated with time savings of 8-19 minutes – that have been judged to be significant contributors to efforts to meet a 90-minute door-to-balloon deadline.133

There is growing recognition of importance of transporting ST-elevation myocardial infarction (STEMI) patients for primary percutaneous intervention (PCI). A consortium panel of U.S. 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.134 Recent meta-analysis confirms the substantial outcomes benefits, in terms of both mortality and morbidity (including from stroke), of timely transfer of STEMI patients for mechanical reperfusion.135 For some regions and patients, HEMS provides a vital capability to meet this benchmark.

The authors of a logistics study from the University of Wisconsin26 noted that HEMS and fast transport is occasionally critical even for patients who are not profoundly unstable, but who may need time-windowed cardiac or stroke therapy. In assessing average transport times from their 20-hospital network, the investigators found that for all hospitals, the average HEMS total transport time over the study period was at least as good as the best ground transport time – and this took into account the fact that for many hospitals ground EMS was on-site at the time of transport. Furthermore, the authors found there was clinically significant time savings for all institutions: patients at close-by hospitals accrued an average of 10 minutes’ time savings, while those from further-out hospitals had HEMS transport times of up to 45 minutes shorter than achievable by ground transport.

5. Minimization of out-of-hospital time

As an additional facet to the time issue, the issue of “out-of-hospital” time (for interfacility transports) should be considered separately from the general issue of “pre-trama 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. In one 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).107 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 an admirable 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 air as compared to ground; the reduction in out-of-hospital times was theorized by the authors to contribute to good maternal and fetal outcomes in their transported population.136

6. Direct transport to specialized centers (for primary/scene missions)

As considered from the point of view of the patient, the benefit of direct transport to specialized centers relates to the debate about whether community or tertiary care hospitals provide better care. For some diagnoses, such as trauma or acute coronary syndromes, a strong argument can be made for bypassing community hospitals in favor of direct transport to larger, higher-volume centers (with more capabilities such as primary percutaneous coronary intervention).137 For areas in which there is no trauma center, air medical scene response for direct transport to the trauma center is often the best course.34

In fact, there is strong evidence basis to suggest that, for blunt trauma patients, bypassing (by HEMS) of community hospitals in favor of direct transport to Level I trauma centers has a significant impact on outcome.110,136-145 In fact, overviews of HEMS’ performance and benefits in rural areas tend to explicitly mention the bypass of lesser-qualified (for trauma) hospitals is a “seldom mentioned benefit of HEMS transport.”145 Experts with no interest in the HEMS debate have noted that “it is beneficial for a patient to be taken to a designated trauma center rather than a non-trauma community hospital.”144 Data from the Centers for Disease Control and elsewhere have confirmed that, for the general population of injured patients, trauma center care (i.e. appropriate triage) results in substantially reduced mortality.109,146 There are substantial implications for HEMS in the (controversial) studies that reveal a distinctly improved outcome from transport to Level I (as compared with Level II) trauma centers.110

A nationwide study of over 250,000 adult and pediatric scene trauma transports from the National Trauma Data Bank (NTDB) is also tied to the Level I vs. other-level trauma centers.73 The finding that HEMS was associated with a 22% improvement in mortality, was discussed by the authors as possibly indicating that HEMS afforded
access to Level I (and to a lesser extent, Level II) trauma center care. A few months after the publication of the NTDB study by Brown et al, the results were confirmed in a study of the same NTDB 2007 dataset, from the Centers for Disease Control; the fact that the CDC study focused only on adults probably explains its larger point estimate (39%) for HEMS-associated mortality benefit.147 The large-scale aspect of the NTDB data that render results so compelling, comes at a cost of inability to tease out reasons for outcome improvement — but even if HEMS transport was nothing more than a marker for capability to get patients to high-level trauma care, the results remain compelling in the “real world.”

It is well known that delays at non-trauma centers, which can result from a variety of factors such as specialist non-availability, prolong pre-trauma center times and worsen injured patients’ outcomes.148-151 Such reports may be reasonably expected to increase utilization of HEMS for such “direct” transfers from scenes to trauma center care. Trauma triage and systems experts have found that patients with head injuries, and those patients with physiologic findings meeting trauma triage criteria, had significantly better outcome when treated at regional centers as compared to area (Level 2) trauma centers or non-trauma centers.152,153 For adult and pediatric trauma patients who are initially treated at non-trauma centers, transfer to Level I centers is associated with substantial improvement in outcome (mortality odds ratio 0.62 as compared to patients kept at non-trauma centers); thus interfacility transfer (which will occasionally be via HEMS) is warranted and appropriate.144 Henry et al write “The considerable improvement in survival raises the question of whether patients meeting these physiologic criteria with improved outcomes should be transported directly to regional centers, even if that means bypassing an area trauma center.”

In a study focusing on the subset of patients with severe traumatic brain injury, and with methodology adjusting for hypotension, age, GCS, and pupillary reactivity, a group of investigators from New York State found that direct transport to a trauma center provided a clear outcomes benefit.154 Authors of that study point out that the Guidelines for Prehospital Management of Traumatic Brain Injury call for direct transport to high-level care, when severe brain injury is present (GCS<9).155 Evidence finding a clear correlation between trauma center status (Level I or Level II) and adherence to well-accepted Traumatic Brain Injury Guidelines, concludes that direct transport for brain-injured patients to trauma centers will improve outcome.156 Data from Europe also strongly support movement of patients with severe brain trauma directly from scenes to tertiary care. Outcomes are worse for those patients who require secondary interfacility transfer after an initial evaluation at a nontrauma center.157

On the nontrauma front, suggestion of potentially growing indications for HEMS “scene” transports of non-injured patients is provided by an evolving literature consisting of both case series (e.g. for primary percutaneous intervention) and sporadic reports (e.g. scene transport to neurological centers for lytic therapy for ischemic stroke).158 A Japanese report finds that, compared to ground ambulance transport, HEMS use in their particular system is associated with a half-hour’s decrement in times to angiographic evaluation and intervention.158 A preliminary report on simultaneous HEMS dispatch and tertiary care hospital cardiac cath lab activation by ground EMS providers making STEMI diagnosis during transport to a referring (non-PCI) hospital, found the pre-HEMS time at the referring hospital was reduced from 79 to 31 minutes.160

The economic factors driving the growing trend towards regionalization of many critical care services will continue to spur investigation into routine use of HEMS for indications that would be considered novel in past years. Early indications that outcomes are improved with stroke care in specialized centers may add to the efforts to integrate transport plans into regional care for this disease.161

While the integral nature of HEMS as part of a system may make it difficult to delineate the specific outcomes contribution made by the helicopter, the HEMS effect is no less important. When considering a report162 that HEMS integration into a cardiac care system allows for diagnostic catheterization to be performed at community hospitals, with rapid air transport for interventional procedures when needed, it is not easy to either prove or refute the critical nature of HEMS for patient outcomes. Similarly, it is not easy to discount the potential benefit to stroke patients, when reviewing a study from north Florida demonstrating the effective integration of HEMS into the stroke system, with resultant extension of the “reach” of advanced stroke care such as thrombolytic therapy.57 The same logic holds true for injured patients undergoing air transport to Level I centers.56 In these cases, direct transport to specialized centers likely benefits many patients. Additionally, the judicious integration of HEMS into a system of care has high probability of accruing benefits to the region itself. These benefits are among other “systemwide” benefits of HEMS, and are considered in the next section.
SECTION VI. POSSIBLE HEMS BENEFITS TO SYSTEMS

If HEMS is associated with mortality (or significant morbidity) improvement, then a regional EMS system’s mission is aided by access to air transport. Whether the EMS region is dealing with increased interfacility transports as a result of implementation of “inclusive” trauma systems or more frequent HEMS deployment to for interfacility movement of stroke patients, air medical transport has a vital role in regionalization of care. Patient-centered thinking should be paramount, but there are additional logistic and economic considerations representing important system benefits from HEMS. Systems optimization is possible only when HEMS is considered as part of the overall care process. Furthermore, to reap maximal rewards from HEMS there must be attention to all details in air transport dispatch, protocols, crew training, and capabilities, governance, and utilization review. This section overviews some of the system-based benefits of HEMS.

A. Extension of advanced level of care throughout a region

Some of the above-mentioned benefits to patients also apply as advantages to regions and EMS systems. For example, HEMS may allow an EMS system ability to provide for early ALS in isolated and/or difficult-to-reach areas which otherwise would be poorly covered. In pointing out that HEMS can cover roughly the geographic area of seven ground ALS ambulances, Hankins has written that “This kind of coverage, in many areas of the country, provides advanced care where it is not otherwise available.” Others considering the U.S. trauma system as a whole, have agreed that at least in some areas of the U.S., the extension of trauma center care provided by HEMS is critical. Analysis of the economics of covering a widespread region using a small number of aircraft, as compared to a large number of ground vehicles dispersed in such fashion as to assure equivalent response times, is complex; preliminary work suggests that HEMS is actually no more expensive than the multiple-ground-unit alternative.

In fact, limitation of the HEMS vs. “highly trained ground EMS” argument to economic considerations ignores the fact that EMS cannot simply fiat into the ground personnel the “high level of training” that comes with concentrated training and experience accorded to HEMS crews. Evidence suggests that even with major emphasis on training, some ground EMS systems have had efficacy difficulties when neuromuscular blockade-assisted ETI protocols were instituted. Previously cited data demonstrating consistent HEMS ETI success and efficacy stand in contrast to the controversial and concerning findings of ground EMS ETI difficulties. Airway management is an example of the difficulties of simply assuming that giving more capabilities to more ground EMS units obviates need for HEMS.

HEMS crews’ capabilities may offer benefits even to patients already at (smaller) hospitals. This is most likely true in rural settings in which facilities may be staffed by individuals with relatively little experience with trauma or critical illnesses.

Air transport’s ability to extend the reach of trauma systems is important in areas with limited specialist coverage. In trauma, for instance, the lack of ready availability of surgical specialists (e.g. neurosurgeons) is translating to an increasing inability of non-Level I centers to care for injured patients. Trauma triage experts have labeled as “undertriage” any instance of transporting to any hospital lacking emergency access to neurosurgeons, a traumatic brain injury patient with potential for requiring neurosurgical monitoring or craniotomy. If this definition of system undertriage is accepted, then HEMS is an important part of minimizing such undertriage in many areas of the U.S. and other countries.

Trauma regionalization saves lives. As long ago as 2008, a consortium panel of U.S. metropolitan EMS medical directors emphasized the importance of transporting patients for trauma center care if they have ISS>15; the group cites a number-needed-to-treat of 11 (to save one life). As trauma systems mature, there is obviously a role for HEMS in the occasional transport of patients to assure that life-saving care is available to more patients throughout a region.

B. Provision of ALS “backup” for parts of an EMS system which have limited ALS coverage

In addition to providing ALS care to remote areas, HEMS can offer a way for relatively isolated areas to get patients to tertiary care centers without necessitating removal of scarce ground ALS resources from the region. One study found that a major reason rural areas use HEMS is they perceive they are unable to cope with losing their limited ground ALS coverage for what can be a 5-hour round trip. For better or for worse – use of HEMS for noncritical patients may not be in the best interest of the system – some regions have come to rely on air transport as a means to assure they will not lose ALS coverage for hours every time a patient requires long-distance ALS transport. Another benefit that is cited, although controversial, is that use of helicopters for longer-distance critical patient transports reduces risks associated with prolonged red-lights-and-siren ground EMS runs.

C. Minimization of transport times

The utilization of HEMS for some transports, and its resultant streamlining of out-of-hospital times, can benefit EMS systems as well as individual patients. Examples of such benefits include faster turnaround and greater availability for
transport. The overall transport time minimization discussed earlier, with respect to trauma, cardiac, and stroke care, should also be viewed as a system benefit. It should be kept in mind, that the total time savings accrued by HEMS is not just beneficial for scene flights; interfacility patients also tend to get to definitive care more quickly with HEMS.\textsuperscript{26,114}

D. Direct transport to specialized centers

Like some of the other advantages potentially accrued by individual patients, this benefit can also be said to be accrued by an EMS system. One purpose of the EMS regional authority is to provide the optimal prehospital and out-of-hospital transport setup so patients can get to where they need to be. In many cases, this will be the closest facility; in such circumstances ground transport will usually be a preferable alternative. However, some patient populations have definite, probable, or possible indications for direct transfer to a specialized center with bypassing of community facilities. Despite the ongoing debate with respect to “inclusive” vs. “exclusive” trauma systems – a debate which entails points outside the scope of this discussion – the fact remains that care at Level I centers improves morbidity and mortality outcomes for many patient types.\textsuperscript{109,115,165-167} Furthermore, HEMS studies commonly identify significant mortality benefit from direct transportation from scenes to tertiary care (rather than initial ground transport to a “stabilizing” hospital first).\textsuperscript{141} Emerging literature makes compelling arguments, from perspectives of both outcomes and cost (e.g. preventing dual workups), for direct transport of certain patient types (e.g. pediatric trauma) to specialized centers.\textsuperscript{168}

As regionalization of care continues to evolve, EMS systems will doubtless play a major role in both primary (i.e. scene) and secondary (i.e. interfacility) transport of an increasing number of patients requiring specialized care. In fact, a 2010 study revealed that centralization of cardiac catheterization resources, with appropriate build-up of EMS transfer systems, is significantly more cost-effective than construction of multiple cardiac catheterization centers; the authors note that 20% of Americans live more than an hour away (by ground) from a cardiac catheterization center.\textsuperscript{169} HEMS’ role in such regionalization is not yet fully characterized, but the existing literature renders clear the fact that air medical transport does have some role in optimizing regionalization.

E. Transport flexibility in overloaded hospital systems

The helicopter offers advantages of being flexible with respect to receiving center; not much time is lost in changing the receiving hospital destination if it is close by, and the helicopter’s speed and range can bring distant hospitals into play if local facilities are overloaded. Though the obvious benefit to this (for EMS systems) relates to unusual circumstances such as disasters,\textsuperscript{170,171} the current environment of hospital and E.D. overcrowding renders the receiving hospital flexibility of HEMS a potentially useful thing.

With the advent of increasing problems due to ambulance diversion, the transport flexibility provided by HEMS has additional advantage. Since ambulance diversion problems can result in a given ground EMS unit being out of service for an extended period (i.e. while it is performing a longer-distance transport),\textsuperscript{141} the aircraft may be able to “back up” the ambulance by either performing the transport or being available while ground EMS is out of service. With increasing evidence demonstrating trauma mortality rates increasing when trauma centers’ EDs are on diversion,\textsuperscript{172} the HEMS unit can serve as a life-saving method for “decompressing” the overtaxed ED. In fact, the utility of HEMS to distribute the patient load, already noted for its potential value in disaster and mass casualty incidents, may be applicable in some areas’ Level I trauma centers on an increasingly frequent basis.\textsuperscript{170} The loss of availability of rotor-wing transport has been recognized as a potential mediator of increased mortality due to decreased capability to execute interfacility transports.\textsuperscript{115}

F. Ability to perform unusual and ad hoc activities

The nature of the helicopter lends itself to utility in unusual circumstances. For example, in the rare 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.\textsuperscript{61} The 2005 London subway bombing mass casualty incident provides an example. In this event, reports Dr. David Baker of the UK’s Health Protection Agency (in a personal communication, June 2007), the London traffic situation rendered HEMS vital. The London HEMS aircraft flew at least 25 missions. None of them were patient transports; the helicopter was used for transportation of medical care teams to incident sites. Others have also discussed the fact that HEMS flexibility translates into multiple potential uses during disaster and mass casualty incidents.\textsuperscript{170,173}

Additional reports from around the world outline unusual use of HEMS resources, which do not justify expense for an aircraft, but which nonetheless represent (in conglomeration) a potentially significant illustration of HEMS’ ad hoc utility. For example, the French have reported HEMS response to cruise ships at sea, enabling time-critical and successful lytic therapy for stroke.\textsuperscript{174}

In addition to transporting people, helicopters have been occasionally used to rapidly transport vital supplies or drugs (e.g. prostaglandins to a neonate with a ductus-dependent lesion). Another “unusual” activity that may for some regions be appropriate for HEMS is performance of research in the out-of-hospital setting. Particularly in rural regions, where the
HEMS crews arrives at patients (both at scenes and at referring hospitals) long before the patient will get to Level I care, it has been suggested that a small cadre of air medical personnel can be trained to intervene/enroll patients in clinical studies with a narrow time window.\textsuperscript{116,175} As is the case with the other activities mentioned in this section, prehospital research is not a justification for HEMS, but it is a noteworthy occasional benefit.
Section VII. Introduction to HEMS Cost-Benefit Considerations

The available evidence supports a contention that some benefits are potentially accrued by HEMS use. Proponents of HEMS interpret the evidence base as demonstrating that air medical transport optimizes outcomes for both scene- 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.

The assessment of costs and benefits is somewhat complicated, involving mathematics, assumptions, and even nomenclature that can be daunting at first sight. The very definitions of study types can be confusing. This monograph’s author—who claims no special expertise in these sorts of analyses—was taught in graduate school that cost-benefit analysis measures outcomes in dollars, cost-effectiveness analysis uses a non-dollar outcome (e.g., lives saved), and cost-utility analyses report a “utility” outcome such as quality-adjusted life-years (QALYS). Unfortunately, the HEMS literature often fails to adhere to these strict definitions.

Those who have delved into the detailed economic analysis required for truly rigorous cost-benefit calculations have noted difficulties in simple maneuvers such as assigning value to human life. Complexity increases when other issues are considered, and comparative analysis requires understanding of all associated costs of both air and ground transport. Average age of patients is necessary, since those who live longer (i.e., who are younger when their lives are saved) yield more “cost-benefit” to the intervention. Additional costs associated with “living” must sometimes be added; those who survive also live to incur more healthcare costs as they age. On a related note, saving lives in the field, only to have the patients die in the hospital (after racking up expensive ICU bills), adversely affects cost-benefit.

Fortunately, some rigorous and independent analysis of cost and benefit data has been conducted. A Canadian Institute of Health Economics report notes that “air medical services appear to be expensive on a single-case basis but not at a system level.” Other overarching reviews also note that the majority of analyses reveal HEMS to be cost-effective. Additional data supporting cost-benefit of air medical services comes from economics studies from two areas within South Africa.

Some of the most rigorous investigations of cost-effectiveness come from Scandinavia. One study, calculating cost-benefit for 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.” Another group from the region estimates that HEMS contributes to the cost-effectiveness of primary percutaneous coronary intervention; even when patients were transported from longer distances (and by air), the cost-effectiveness of primary PCI over time is maintained.

The Norwegians’ estimate (a benefit-to-cost ratio of 5.87:1) indicates that the HEMS operations quite easily paid for themselves, and in fact reaped a substantial “return on investment” for society. In a study conducted in nearby Finland, authors calculated that the cost of HEMS, per beneficial mission, was roughly $30,000. The arrival at these numbers entails economics analyses that are difficult to briefly overview, but the importance of the topic warrants its incorporation into any discussion of HEMS outcomes.

It is helpful to consider that excellent cost-effectiveness studies have in fact been executed in areas with “real-world” trauma triage imprecision. 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. Therefore, any refinements in triage (see Triage section of this discussion) will only improve the cost-effectiveness of HEMS.

A. Cost-effectiveness

The quantitative approach to assessment of costs and benefits generally incorporates analysis of cost-effectiveness (sometimes called cost-utility, as noted above). This approach ties a specific dollar cost to a specific measure of “benefit” where benefit is optimally defined in units of quality-adjusted life-years (QALYS). 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, and “imperfect health” is assigned a positive fraction of 1. 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.

After one performs a cost-benefit calculation, the next step may be 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 true 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.
B. General application of cost-effectiveness to the question of HEMS vs. other transport modalities

As just noted, HEMS may appear to be an expensive method to transfer patients. In fact, no one would argue that the cost of the average helicopter isn’t far greater than the cost of an average ground ambulance. Of course, the true situation is far more complicated, since the costs should be applied for a given regional system. A few air medical assets provide advanced level care (and usually more rapid transport capability) that would require a fleet of ground EMS units (and correspondingly more personnel). The size of the fleet differs depending on geography and other factors, but one estimate based upon miles traveled for the average ground EMS unit, calculated that coverage of one helicopter’s annual travel distance would require 3.3 ground ambulance – and the cost of the air ambulance was equivalent to 3.2 ground EMS units.178 Thus, exploration of the “regional coverage view” has resulted in at least two economic studies concluding that HEMS is less expensive than development of a wide-ranging fleet of ground EMS vehicles.2,179

Complex cost considerations are beyond the scope of this discussion, but there has been excellent work, that paints a picture of the myriad factors that should be considered when trying to adjudicate true costs of EMS systems and components.178,179,183 The healthcare economist assessing costs and benefits of HEMS should consider, as one of many examples, that HEMS-associated outcome improvements for head-injured patients are particularly well characterized, and doubtless save substantial sums in long-term care costs.5

Cost-effectiveness determinations also become tricky when one considers uses for HEMS for transports that would either simply not occur (as with high-risk obstetrics transports)185 or would not occur within a critical time window (as for stroke or cardiac transports).58,131 There is no ground transport option capable of rapidly moving through rush-hour traffic in Los Angeles;41 there is no realistic surface vehicle option for stroke or cardiac patients on Nantucket (an island off coastal Massachusetts) who need timely transport to neurointerventional or cardiac catheterization suites.131 The geography of cost-effectiveness calculations has been highlighted in other countries, too. Analysis finding air transport cost-effective in South Africa includes discussion of the difficulties (and costs) of providing a ground transport alternative. In combination with the earlier-presented information that HEMS represents the only mechanism by which over 80 million U.S. citizens have timely access to mortality-improving high-level trauma center care,108 it becomes obvious that HEMS is a “must-have” for some U.S. EMS regions. The direct bearing on the cost-effectiveness calculations is obvious. If a region must have air medical assets for some group then it’s appropriate for cost-benefit calculations to spread the “overhead” costs across all transported patients. Put another way, if Massachusetts must have a helicopter to annually transport hundreds of patients off of Nantucket and Martha’s Vineyard, what is the best way to define and analyze the additional costs of providing transport for other regional patients, once the helicopter is “already bought”? Mounting evidence shows that the best mechanism for improving trauma mortality is to get significantly injured patients directly to a tertiary trauma center.109,143 Transporting such patients to a lower-level trauma center as an intermediate step before Level I care not only risks worsening outcome, but also incurs significant costs. Studies from over a decade ago suggest that the extra hospital “stop” adds about $700 to per-patient transport expenditure,184 and an equivalent cost (at least) in repetition of laboratory and radiology evaluation.185 The costs have doubtless increased over the years. Retrospective review of one system’s experience with direct-from-scene (HEMS) transport directly to tertiary care, versus ground transport to rural facilities (with frequent subsequent transfer to trauma centers), finds that HEMS and ground modalities have equal cost (the authors do not address benefit of direct-to-trauma center transport).184 Thus, direct-to-tertiary transport should enter into cost-benefit calculus, just as it should be considered in discussions on HEMS outcomes.

Capital equipment is not the only cost arena that can be tricky in cost-effectiveness 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.”

C. Specific calculations for HEMS cost-effectiveness

It is clear from the preceding discussion that true costs of HEMS operations are not easy to study, given complexity of the HEMS programs and the difficulty of ascertaining incremental costs of HEMS over “critical care-trained ground EMS.” This probably explains why there are not a large number of cost-effectiveness studies from the U.S. However, there is guiding literature, and it is informative. In fact, given the infrequency with which existing data are cited, the reader may be forgiven for some surprise upon finding that the extant evidence is consistently in favor of cost-effectiveness of reasonable HEMS use. Some examples of that literature will be discussed in this section.

In 2005, a California HEMS group identified an incremental cost of fuel and maintenance (not including fixed costs) of
$650 per flight hour.\textsuperscript{186} The same year, a South African economic analysis\textsuperscript{179} calculated the actual, all-source cost of HEMS operations at US$1800 per hour of operation. (The South Africans calculated FW operations cost to be US$1400). While this is not inexpensive, the number must be considered in the context of other healthcare expenditures for the HEMS-transported population. The stakes are high: the CDC’s Division of Injury Response estimates lifetime U.S. medical costs for the care of the acutely injured to approach $80 billion annually.\textsuperscript{146} With over 29 million nonfatal injuries annually seen in U.S. EDs, the magnitude of the challenge of appropriate cost containment and triage becomes apparent.\textsuperscript{146} Other investigators have executed economic analyses and concluded that HEMS response to the scene, with direct transport to trauma centers, is beneficial and also cost-effective.\textsuperscript{184}

While the reader is referred to other sources\textsuperscript{85,187} for detailed explanation, a general estimate of cost per life-year saved for adult trauma transports was calculated in 1997 to be in the range of $2500 given the industry-standard transport cost and a W estimate (see TRISS discussion above) of \$; the cost/life-year rose to \$9,700 if W is set at 1. The authors noted that for pediatrics, the survivors’ greater expected longevity would offset the lower estimate for W.

Those cost-benefit results are “old” (1997 dollars), but the absence of rigorous new cost-benefit analysis in the U.S. means the 1997 evidence is still worthy of discussion. For contemporary comparison against cost-benefit of other medical interventions from the same late-1990s time frame, the following table is informative. The HEMS cost per life-year saved of under \$10,000 compared favorably to the following:\textsuperscript{187}:

<table>
<thead>
<tr>
<th>Intervention</th>
<th>Cost (1996/1997 $) per life-year saved</th>
</tr>
</thead>
<tbody>
<tr>
<td>neonatal ICU for birth weights 500-999g</td>
<td>$18,000</td>
</tr>
<tr>
<td>median for 310 medical interventions</td>
<td>$19,000</td>
</tr>
<tr>
<td>3-vessel coronary bypass for severe angina</td>
<td>$23,000</td>
</tr>
<tr>
<td>thrombolytic therapy for acute MI</td>
<td>$32,678</td>
</tr>
<tr>
<td>prophylactic AZT after needlestick injury</td>
<td>$41,000</td>
</tr>
</tbody>
</table>

If costs are considered in current dollars, HEMS continues to appear reasonable. Though the “acceptable” threshold for interventions is not specifically defined, policy and medical experts writing in the field place it anywhere between \$50,000 and \$100,000 for the U.S. and the U.K.\textsuperscript{182,188,189} One pediatric trauma paper (notable for its excellent explanation of cost-effectiveness analytic methodology) endorsed use of \$100,000 per QALY as a threshold for acceptability.\textsuperscript{190} Recent (2012) studies in prominent journals such as JAMA continue to use a threshold of \$100,000 to define favorability.\textsuperscript{191} A 2009 detailed survey of cost-effectiveness analysis from a prominent university in the Netherlands finds the threshold for acceptability to lie between 25,000–75,000 euros (about \$32,000-95,000 in US dollars).\textsuperscript{100} The same Dutch authors (who include both traumatologists and health-economy experts) note that HEMS’ cost-effectiveness compares favorably to that of heart, lung, or liver transplants in the Netherlands (with cost/QALY ranging from about \$50,000-100,000 in US dollars).\textsuperscript{100}

Estimates for cost-effectiveness are generally consistent across different countries and investigators. In a report prepared for the British government’s Department of Health,\textsuperscript{192} Nicholl and colleagues reported that the cost per QALY was \$10,000-30,000 (after currency translation to dollars). They noted that this was consistent with estimates from Norwegian studies, and that the estimated cost per QALY was within the UK’s “acceptance threshold” of about \$35,000 (this study was over a decade ago). Data from Australia find a similar range for cost-benefit (depending on model assumptions); using over a decade of actual trauma transport data in New South Wales, Taylor et al calculated HEMS’ cost per life-year saved to be in the range of \$50,000-97,000.\textsuperscript{193}

Research from the Netherlands\textsuperscript{194} indicate that, when the public is surveyed, there is willingness to pay far more (nearly \$20/household/month) than the actual costs of HEMS provision. These data complement available evidence from other Dutch investigators who report that in the Netherlands, HEMS’ cost-effectiveness is between \$10,000 and \$50,000 per QALY (depending on the specific models used for calculations).\textsuperscript{100,195}

Interpretation of these cost-benefit studies can be daunting for those without a bent for economic analysis. Further complicating the issue is that HEMS costs should probably fairly be compared as incremental costs over ground EMS provision of care. In urban settings, where ground EMS coverage is plentiful, those costs may be small, but the story is different in many rural areas. In fact, one economic study has calculated that covering a broad expanse with rapid-response, high-level care is actually less expensive with HEMS than it would be with similarly advanced ground EMS resources (per-patient costs in 1991 dollars: $4475 HEMS vs. $2811 ground EMS).\textsuperscript{2} (That analysis is predicated, by the way, upon an assumption that the skills attained by HEMS crews can be assumed present for ground EMS.) Overall, while data are necessarily suboptimal, it seems fair to conclude that in terms of dollars expended per life-year saved, HEMS (at $2454) is probably less expensive than ground EMS ($8886).\textsuperscript{2,196} In fact, the job of assessing HEMS’ cost-effectiveness is made more difficult by the extremely limited amount of information on cost-effectiveness of ground EMS itself.\textsuperscript{197}
Recent work demonstrated significant mortality benefit associated with HEMS use for trauma, has included emphasis on the need to include nonmortality benefits in cost-effectiveness assessment. Limitation of cost-effectiveness to simple mortality reduction is likely to underestimate the true financial benefits that can be accrued with HEMS.

Though most extant information addresses use of HEMS for trauma, it should be pointed out that cost-effectiveness calculations are increasingly being applied to other patient populations. An example of such work is that of Silbergleit et al., who demonstrated HEMS cost-effectiveness for acute ischemic stroke (for thrombolytic therapy).

Detailed economical analysis is beyond the scope of this discussion. The data presented in this section are intended only to familiarize the reader with some basic concepts, and to provide some tools that might be useful in executing a rigorous cost-benefit analysis. It is hoped that the data presented will allow the reader to appropriately evaluate such broad-based claims as “the helicopter is expensive” from a rational, health-policy standpoint. HEMS represents a resource-intensive effort, and both common sense and available data support the notion that the best cost-effectiveness will be achieved by a rational and evidence-driven transport process that involves both air and ground modalities.
**SECTION VIII. OPTIMIZING HEMS UTILIZATION: AN OVERVIEW OF TRIAGE**

As is the case with any other medical resource, HEMS should be used only when appropriate. Whether the indications relate to chance for patient improvement or time-distance factors and “protection” of ALS coverage for a given region, HEMS dispatch should be performed only when there is potential advantage over transport by surface vehicle.

No guidelines for dispatch are ideal, and authorities on the subject recognize the inevitability – and necessity – of some degree of HEMS overtriage. For one thing, in the realm of nontrauma the development of evidence-based HEMS triage criteria is limited by a dearth of applicable quality literature. Even in the realm of trauma, HEMS triage appropriateness has been identified (even by “pro-HEMS” experts) as an area in need of major refinement. It can be persuasively argued that, as an agenda item for further research, improving HEMS triage is even more important than generation of further “outcomes” studies. In the words of one trauma surgeon, from a U.S. government agency (NHTSA) report on care for the injured:

“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. The goal is to facilitate air medical care when needed, and avoid overutilization when not needed.”

The above-cited NHTSA report goes on to point out that the current triage system needs help. The authors aver that while better scene HEMS coverage is of high import for reducing injury mortality, there is a clear need to “develop information systems and protocols that help to distinguish those who are likely to have serious injuries from those who are unlikely to have serious injuries.” This section of the HEMS discussion cannot replicate or even completely overview the complex and often frustrating subject of triage; rather, some of the overarching pertinent points will be addressed.

Before delving into the challenges of developing triage criteria, it is worth considering, that even after criteria have been implemented, regions will have varying degrees of compliance with “agreed-upon” protocols for HEMS use. The broad variability in HEMS use, in areas operating under the same triage guidelines, has been demonstrated from areas as disparate as New England and the Netherlands. Thus, as important as it is for HEMS services (and EMS regions) to establish triage guidelines, it is just as important for regions to assure that their constituent HEMS activators actually follow the existing criteria applicable to their use of air medical resources. Well-executed studies reporting years of experience, demonstrate that the correct use of these triage guidelines, even in the most rural settings, can result in optimal HEMS triage even without requiring base station contact.

A final consideration before delving into the triage issue, is one that should give some grounds for optimism. As difficult as triage is, and as much as the currently available system needs improvement, studies do show that HEMS is improving mortality – particularly with respect to trauma patients. In fact, the same investigators examining the same EMS regions, tend to demonstrate both poor triage and overall mortality improvement. Furthermore, nationwide population-based analysis of over a quarter of a million trauma transports in the U.S., demonstrated a 22% survival improvement with HEMS (as compared to ground EMS) transport from the scene – and this study obviously included areas in which triage was suboptimally refined.

The fact that data indicate overall HEMS mortality improvement, even when assessed in real-world settings with real-world flaws in triage, does not obviate discussion of triage improvement. However, it does mean that even with admittedly imprecise triage, HEMS is still associated with outcomes benefit. With that acknowledgment, the conversation may now move to the important task of improving HEMS utilization.

A. What is the definition of overutilization?

There can be little doubt that when viewed from a large-sample, post-transport perspective, HEMS overutilization is rampant if overutilization is defined as execution of missions for which transport mode appears retrospectively to have had no impact on outcome. In fact, medicine does not operate on such a specious definition of overutilization. Of myriad examples that would occur to any clinician, one sample analogy would be considering “overutilization” represented by negative imaging tests. No one would disagree with the absurdity of uniformly characterizing as “radiology overutilization” any instance in which acranial computed tomography scan is negative. Consideration of the issue of HEMS overutilization should be rigorous but level-headed: post-hoc determination that HEMS transport didn’t impact outcome is a necessary, but not sufficient, requirement for defining a flight as unnecessary. Further comments on the terms “overutilization” and “overtriage” are found below.
B. How should the rate of overtriage be calculated?

On a case-by-case basis, HEMS overtriage should be defined as occurring when the use of the aircraft transport mode offered insufficient advantage (logistical, clinical, etc.) to justify the resource expenditure (i.e. the expenditure over and above that incurred by ground EMS transport). The advantages may accrue to the patient being transported, to the region as a whole, or to both. The resource expenditure is not only monetary, but entails consideration of other “costs” such as risk (to crew) and opportunity cost (since the aircraft can only do one mission at a time).

C. What rate of overtriage is “acceptable”?

Introduction to over- and undertriage

Some level of overtriage must be accepted, in order to optimize chances of getting truly needy (but perhaps not obviously identifiable) patients to trauma center care. Though most literature addresses overtriage, the fact is that undertriage is a well-recognized cause of increased morbidity and mortality in the trauma population. 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. As previously noted, 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.

For trauma systems in general (i.e. triage to high-level trauma center care), the American College of Surgeons has stated that “an undertriage rate of 5-10% is considered unavoidable and is associated with an overtriage rate of 30-50%.” In fact, 50% is the most commonly reported acceptable overtriage rate but studies report trauma systems overtriage rates ranging to 90%. This level of overtriage has been cited by prominent traumatologists who have particular expertise in prehospital care systems. The current truth, according to field triage reviews, is that there is no universally accepted rate of appropriate overtriage and undertriage, and in fact there is no gold standard for measuring triage accuracy in the extant literature.

Just as there are no clear guidelines for triage appropriateness, the literature provides little clarity on the question “how well is triage currently being performed?” Certainly, some authors have identified gross deficiencies (e.g. regions lacking HEMS triage guidelines) and others have identified low ISS and high rates of early hospital discharge. However, nationwide data (assessing over 250,000 ground and air scene responses) finds that HEMS patients are in fact far more acutely injured, and require far more hospital resources, than ground EMS patients.

The 2010 Brown et al NTDB study includes a number of findings relevant to triage in the U.S. The actual rate of discharge from receiving hospitals within 24 hours of flight, is much lower (<15%) than previously speculated. The authors conclude 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.” National-level data indicate that HEMS patients are definitely high-acuity: almost half require ICU admission, a fifth are mechanically ventilated for an average of 7 days, and nearly a fifth require urgent operative intervention. Even the ISS question seems to be related to distance; while 57% of HEMS patients in the nationwide NTDB study had ISS <15, this average ISS fell below this critical value only for those patients with transport times of over 2 hours.

Urban HEMS use and overtriage

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 assignment, based upon estimation of travel times, of theoretical ground EMS times. This approach (as used by Shatney and other investigators) ignores the critical import of ascertaining 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 assessment. In a letter prompted by the study of Shatney et al, a trauma orthopedist noted that the HEMS was of utility in his own urban system, particularly when traffic congestion, access issues, or bumpy roads (for spinal trauma) were a problem. Furthermore, the work of Svenson et al is illuminating: when assessing actual HEMS and ground transport times in their 20-hospital referral network, the University of Wisconsin group found that HEMS saved at least 10 minutes in overall transport time (for close-by hospitals) and the time savings ranged up to 45 minutes (for hospitals furthest away). Transport time calculations revealed a clinically significant time savings even when accounting for the facts that HEMS had to get to the referring facility (whereas ground EMS was often on-site at referring hospitals) and that physician-staffed HEMS crews often had much longer pre-transport stabilization time (due to performance of more pre-transport procedures).

The work from Wisconsin is important in that it takes time-distance calculations into the interfacility realm. In fact, criticism of HEMS “overutilization” has tended to focus far more attention on scene, as compared to interfacility, transports. One of the largest recent reviews of HEMS overutilization discarded outcomes studies incorporating interfacility
transports; this approach implies that interfacility overtriage is not a problem. In fact, interfacility overtriage is a distinct problem. In Oklahoma, interfacility patients are substantially less likely to have ISS >15 and are substantially more likely to be discharged within 24 hours, as compared to scene HEMS patients (unpublished data from Oklahoma State Department of Health). Recent assessment of over 10,000 injured patients undergoing initial evaluation at 43 non-trauma center community/rural hospitals in Oregon found that even after adjusting for patient and hospital-logistic characteristics, there was substantial heterogeneity between different institutions’ transfer practices. When it comes to transferring patients (by either ground or air), there seems to be room for improvement regardless of whether transport decisions are made by community hospital physicians or prehospital providers.

**Logistics and triage**

There are those who posit that specific time/distance considerations should be the major trigger for HEMS dispatch. For instance, it’s been written that ground transport times of at least 30 minutes are consistent with need for HEMS transport for head trauma patients. Others content that simultaneous HEMS and ground EMS dispatch becomes time-beneficial when patients are at least 10 miles from the receiving trauma center, but they acknowledge their scheme results in a frequency (55%) of cancelled flights that would stretch the financial resources of any HEMS program. The same authors also found that for nonsimultaneous dispatch of helicopter resources, air medical use provided the fastest transport modality if the distance from trauma centers exceeded 45 miles. This number approximates the distance identified in a 2009 study in Australia, in which it was determined that HEMS saved pre-trauma center time only when transport distances exceeded 100 km. In fact, the range of approximately 45 miles from the trauma center is endorsed by those executing large-scale studies of HEMS trauma scene response. This distance may serve well, at least as a starting place, to inform logistics assessments for a given region.

Other investigators have drawn different conclusions, illustrating the heterogeneity of logistics situations in varying regions. For instance, Minnesota’s use of “autolaunch” (HEMS dispatch based upon reports by lay passersby, before on-scene arrival of law enforcement or first responders), while associated with only a 21% mission completion rate, was found to have favorable cost-benefit analysis. The Minnesota report emphasized a number of factors designed to insure judicious resource utilization (e.g. medical oversight, cancellation by first responders arriving on-scene, strict utilization review), and they have also predicted that automated information recording and reporting capabilities (e.g. OnStar) will combine with Global Positioning System technology to improve autolaunch cost-effectiveness.

In a largely rural setting, Lerner et al found that the use of HEMS saved an average of 13 minutes when used for patients between 6 and 15 miles from the receiving trauma center. In an Ontario study in which referring and receiving hospitals lacked on-site helipads, the use of HEMS did not appear to save any time over ground transport when measured from the time of transport decision to trauma center arrival (there was little information about stabilization time by HEMS crews, but the authors did note that HEMS patients were of much higher acuity). Importantly, the Ontario authors assessed ground-vs.-air transport times from hospitals, and found that factors other than distance were often important contributors to the determination as to which transport modality would be faster. Another study has suggested that HEMS be reserved for cases where ground transport to appropriate trauma centers exceeded 45 minutes for patients with sufficient criticality (e.g. airway issues, shock, reduced level of consciousness, head or facial injury). The authors also incorporated into their transport mode decision algorithm, logistics such as whether the receiving hospital’s helipad lies within a “trolley’s push” of the ED. As demonstrated in Ontario and in other settings, time benefits of air transport are optimal only if the referring and receiving hospitals have ready access to helipads.

One aspect of logistics that must be incorporated, although with regional variation, is the balancing of need for HEMS for high-acuity patients, with the need for HEMS as the only viable option for long-distance scene response. In the nationwide NTDB study from 2010, prehospital transport time was associated with ISS, with the average ISS falling under 15 only for those patients with prehospital transport time exceeding 2 hours. It may or may not be appropriate to use air medical resources for a 130-minute one-way flight, but the logistics/acuity calculus for assessing appropriateness is certainly different at such a great distance, as compared with a short flight time.

Unfortunately, some of the largest datasets available for use in HEMS research have limitations preventing definitive logistics conclusions. Galvagno et al, in their JAMA paper discussing HEMS’ outcomes benefits identified for scene trauma, note that NTDB’s data problems precluded inclusion of transport distances in their regression models.

Though it is a small part of HEMS use in the overall picture of prehospital systems worldwide, the logistics capabilities of the helicopter are critical to enable access to some patients. In an alpine setting, for example, the helicopter’s ability to get to patients for rescue, is at least as important as any advanced medical care the HEMS crews render. The logistics of triage are complicated, as has been pointed out by trauma systems experts. Examining isolated cases where HEMS appears to be unhelpful risks substantial underestimation of the HEMS mortality effect, and equally risks underestimation of the increase in mortality that would result if HEMS is removed from a given system. Thus, as triage
efforts with respect to logistics (and clinical parameters) are refined, EMS regions must take a system-wide view.

**Imperfection of known triage guides: Need to go beyond anatomic and physiologic criteria**

A 2012 JAMA study identifying significant mortality improvement associated with HEMS use for patients with ISS at least 15 (the only patients studied), included the following disclaimer: “To date, the development and use of effective prehospital triage tools that can identify adults with a high ISS have remained elusive.”

Other discussants of triage conclude that “The decision to use a helicopter is not straightforward, and a number of important geographical, physiologic, and pathologic factors need to be considered.” In other words, it is easy to argue that currently extant HEMS dispatch criteria result, in some cases, in deployment of the helicopter for patients who in retrospect did not need the aircraft. What is far more difficult to do, is use available evidence to support specific changes to currently used triage guidelines. The question is how to use *prospectively available information* (*i.e.* not retrospectively calculated scores such as ISS) to maximize triage sensitivity while maintaining acceptable positive predictive value.

The authors of one paper highly critical of HEMS overtriage state that “future studies should critically evaluate each mechanism of injury and physiologic criteria to determine the best predictors of helicopter usage.” That statement is reasonable, but it must be interpreted in light of extant trauma triage research. For instance, the critics’ suggestion of using GCS and heart rate (in the manner of a speculation by Moront et al.) manages to combine a poorly sensitive variable (GCS) with a parameter (heart rate) that is quite nonspecific. Such an approach has demonstrated nonviability in the trauma triage literature (see Henry et al., among others).

It is well known that limiting triage decisions to anatomic and physiologic variables results in dangerous and inappropriate levels of undertriage, and that some level of prehospital provider judgment (and mechanism of injury) is necessary to optimize outcomes. On the other hand, it is just as clear that some of these additional triage markers such as mechanism of injury, nearly inevitably lead to overtriage. The situation is easily identified as one in which help and improvements are needed, but again, it is not so easy to generate and test solutions. Hedges wrote in mid-2006 of the triage problem: “Primary (field or EMS) triage systems based on physiologic and anatomic injuries will always be limited because vital signs and neurological status are variable in the prehospital setting and/or may be altered by drugs or alcohol, and injuries may be relatively occult with delayed development of physiologic derangement despite the presence of major underlying injury.” (In fact, just as paramedic judgment remains an important component with demonstrated potential to improve prehospital triage, “physician discretion” remains an important part of secondary/physician triage.)

Ongoing work is clarifying contributions from various aspects of triage. The many previous studies of field triage have been overviewed in a review by Lerner. Some of the highlights of the extant literature include relatively consistent findings that, to achieve sensitivity in the 95%-or-higher range, positive predictive value falls to under 10%. In an air medical transported patient population, the ACS triage criteria were associated with an admirable 97% sensitivity – but at a cost of specificity of 8%. In the HEMS patients studied by Wuerz et al., limitation to anatomic and physiologic triage criteria yielded a suboptimal sensitivity of 87%, and was still associated with poor specificity of 20%.

Population-based New York trauma registry analyses reported by Henry et al. revealed many interesting findings. Many mechanism criteria (*e.g.* crash speed >20 mph, >30-inch vehicle deformity, axle displacement) incurred substantial specificity cost while adding little sensitivity. Even anatomic and physiologic criteria, combined with “mechanism” criteria known to be useful (*e.g.* same-vehicle passenger death), had limitations when attempts are made to increase sensitivity to the 90-95% range that is optimal. Analysis of the New York data revealed that, to improve trauma triage sensitivity from 85% to 95%, approximately 100 additional (overtriaged) patients would have to be transported for each “true positive” patient picked up by the loosened triage criteria. The State of New York made a decision to incorporate as independent physiologic triage criteria, pulse rate of <50 or >120; this was based upon the fact that 26% of the patients in the registry who had pulse abnormalities as their only criteria, required major operative intervention. Finally, the New York experience revealed that anatomic and physiologic criteria alone failed to identify 43% of patients requiring operative intervention. Henry et al. concluded that the suboptimal performance of anatomic and physiologic criteria alone “highlights the need to use mechanism criteria and the need to accept overtriage.” They reiterated importance of utilizing criteria such as age>55, cardiac/respiratory disease history, coagulopathy, Type I diabetes, cirrhosis, and morbid obesity.

An Australian study finds that even the most seasoned (HEMS) paramedics were able to achieve acceptable triage sensitivities only with high levels of overtriage. Using a composite indicator of “serious injury” that comprised such variables as ISS exceeding 15, need for >24 hours’ ICU stay, or urgent operative intervention, the Australians report that flight EMTPs were able to identify serious trauma status with 97.7% sensitivity, but with only 28.2% specificity. Even with the best-trained prehospital providers performing the triage, the overtriage rates in the Australian study ranged (depending on endpoint definition) from 31-47%. Recent information from the Emergency Medical Services Outcomes Project (EMSOP) has concluded that, of all “calculated on-scene” scales and scores in use for trauma risk adjustment, “only GCS...
can be firmly recommended as a specific risk adjustment measure for prehospital trauma research." It seems unlikely that there will soon be an answer to the question of how to perform on-scene triage with precision. The Australian study reasonably used an ISS cutoff of 15 to define “major” injury. Others have used lower ISS scores to define possible need for HEMS. Still others have demonstrated definitive improvement with HEMS use (statistically significant W of 8.8), for patients with ISS scores > 11. An Australian study in 2012 demonstrated cost-effectiveness of HEMS use for trauma patients with ISS>12. Therefore setting the cutoff for HEMS use at 15, fails to identify some patients for whom the available evidence firmly suggests outcomes improvement and cost-effective HEMS use. The problems associated with the ISS’ retrospective nature, are compounded by the difficulties of setting an appropriate cut-point to define when HEMS should or shouldn’t be used.

Even the most fundamental criteria can have problems in field application; things tend to be more complicated in an actual on-scene situation. For example, on-scene assessment of blood pressure is known to be consistently overestimated through the common use of automated blood pressure devices. Should triage rules require manual blood pressure assessment? Given the known association between injury severity and even a single episode of field hypotension (i.e. with normal blood pressure upon trauma center arrival), prehospital blood pressure is a critical assessment—yet questions remain about how it should be measured. This is yet one example of the limitations of any system that attempts to determine HEMS dispatch based solely on the “simple” approach of anatomic and physiologic criteria.

**Ongoing triage refinement efforts and utilization review**

Those concerned with HEMS triage should keep in mind that the American College of Surgeons accepts up to 50% trauma center overtriage in order to achieve optimal trauma system sensitivity. Even given this, commentators note that “substantial undertriage of serious trauma patients to trauma centers appears to be occurring, especially in older persons and in persons with brain injuries.” The same commentators note that overtriage seems to be prevalent at the other end of the age scale, citing a well-executed study from Washington D.C. which found that HEMS saved “only” 11 lives per 1,000 transports. In fact, it is well known that referring physicians (like prehospital providers), are much quicker to activate transport of pediatric patients. Perhaps the extra precaution in children—who represent an enormous potential for trauma systems’ impact on quality-adjusted life-years—is wasteful, and perhaps it is not. The risks of undertriage are serious, and include “diagnostic and treatment delays, diagnostic and treatment errors, increased morbidity and mortality, decreased functional outcomes, or missed injuries.”

A detailed discussion of triage triage can be found in *Prehospital Emergency Care*’s July-September 2006 issue. Unfortunately, a (well-done) paper in the same journal 6 years later shows that there is still no fine-tuned mechanism for triage. Cudnik et al show that the best multivariate model they could generate for predicting composite outcome, had only a 57% sensitivity (and still overtriaged nearly a third of patients).

One of the most important consensus opinions from that group of papers, as summarized by the organizers of the CDC’s Field Triage meeting, 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.” Some high points include the following areas in which there is solid evidence: 1) rapid transport to trauma centers saves lives; 2) much of the U.S. population can only reach Level I centers in timely fashion by HEMS; and 3) trauma transport decision-making is heterogeneous and inconsistent even when physicians (at community/rural hospitals) are doing the triage.

With physician-executed “secondary” triage (from non-Level I centers to higher-level trauma center care) being identified as having multiple problems ranging from undertriage to delayed triage and even threats from EMTALA (Emergency Medical Treatment and Active Labor Act), it is clear that the prehospital setting is not the only one in which triage is tricky. It seems difficult, if not unfair, to expect that prehospital “primary” HEMS triage will be significantly better than secondary triage (i.e. triage occurring from community hospitals). This is especially true given recent findings that prehospital triage (for trauma) appears to be just as good as triage by physicians, as defined by similar ISS, RTS, ICU and hospital lengths of stay, or disposition. Until ongoing efforts to refine trauma center triage further illuminate triage issues from system and HEMS perspectives, it is wise to concentrate on utilization review to identify areas in which HEMS dispatch departs from (imperfect but still useful) regional criteria. Furthermore, the word “overutilization” (which implies preventable inappropriate use) should probably be avoided in favor of “overtriage” since the latter term implies “overuse” that is not knowable as such, at the time of HEMS dispatch.

Both sides of the HEMS debate agree that future research efforts should focus on refinement of triage. Until such ideal triage data exists, and regardless of the imperfection of the available science, those involved in HEMS have a duty to utilize whatever data are available to generate sensible guidelines for helicopter dispatch. Though any system of guidelines will have flaws, the alternative of haphazard HEMS dispatch without regional cooperative planning is not acceptable. Along these lines, the National Association of EMS Physicians generated updated Guidelines for Air Medical
Dispatch in 2003\textsuperscript{234} (reproduced in the attached Appendix). These Guidelines have also been endorsed by the Air Medical Physician Association (AMPA) and the Association of Air Medical Services (AAMS), as well as the American Academy of Emergency Medicine (AAEM). The full Guidelines (including explanatory text) are available and accessible without charge from the website of NAEMSP (http://www.naemsp.org/positionpapers.asp). Given the constraints imposed by the extant evidence, the Guidelines probably represent the best and most up-to-date resource for those wishing to optimize HEMS dispatch. Appended to the end of the Guidelines is a general set of questions which may be useful for determining optimal vehicle response in a given situation. As has been noted in both the initially promulgated guidelines and in other writings of trauma triage experts, it is of vital import for a given region to adapt triage guidelines as indicated by their particular circumstances.\textsuperscript{148}

As a final point on HEMS utilization, it should be emphasized that employment of any Guidelines should be part of a regionwide, cooperative process that incorporates all affected parties (from EMS to community hospitals to receiving centers). Furthermore, the \textit{a posteriori} follow-up of HEMS utilization is clearly critical to determining whether the ongoing utilization of HEMS in a particular region is optimal. Even though nearly all HEMS services are constrained by laws that require them to respond when called, the retrospective utilization review process – if applied in a cooperative atmosphere – can be an integral part of reducing unnecessary HEMS dispatch and optimizing utilization of scarce resources.

New guidelines for HEMS dispatch are being developed, and are based upon the CDC’s Field Triage Criteria. The new guidelines are just approaching publication but they essentially call for time-based dispatch of HEMS for patients meeting the higher-level criteria for trauma center transport. This monograph’s author is participating in generation of the new CDC guidelines for HEMS (which are also to be endorsed by NHTSA); the most up-to-date information on the guidelines can be obtained by emailing the author.
SECTION IX. NAEMS Guidelines for Air Medical Dispatch

1. General
   a. Patients requiring critical interventions should be provided those interventions in the most expeditious manner possible.
   b. Patients who are stable should be transported in a manner which best addresses the needs of the patient and the system.
   c. 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.
   d. Patients with critical injuries or illnesses should be transported by a team that can provide intratransport critical care services.
   e. 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.

2. Comparative considerations for air transport modes
   a. Rotor-wing
      i. Advantages
         (a) In general, decreased response time to the patient (up to approximately 100 miles distance depending on logistics such as duration of ground transfer leg)
         (b) Decreased out-of-hospital transport time
         (c) Availability of highly trained medical crews and specialized equipment
      ii. Disadvantages
         (a) Weather considerations (e.g. icing conditions, weather minimums)
         (b) Limited availability as compared to ground EMS
   b. Fixed-wing
      i. Advantages
         (a) In comparison to rotor-wing, decreased response time to patients when transport distances exceed approximately 100 miles
         (b) In comparison to ground transport, decreased out-of-hospital transport time
         (c) Availability of highly trained medical crews and specialized equipment
         (d) In comparison to rotor-wing, less susceptibility to weather constraints
      ii. Disadvantages
         (a) Requires landing at airport, with two extra transport legs between airports and the patient origin and destination
         (b) In comparison to ground transport, more subject to weather-related unavailability (e.g. icing, snow)
         (c) 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)

3. Logistical issues which may prompt the need for air medical transport
   a. Access and time/distance factors
      i. Patients who are in topographically hard-to-reach areas may be best served by air transport.
         (a) In some cases patients may be in terrain (e.g. mountainside) not easily accessible to surface transport.
         (b) Other cases may involve need for transfer of patients from island environs, for whom surface water transport is not appropriate.
      ii. Patients in some areas (e.g. in the western U.S.) may be accessible to ground vehicles, but transport distances are sufficiently long that air transport (by rotor-wing or fixed-wing) is preferable.
   b. Systems considerations
      i. In some EMS regions, the air medical crew is the only rapidly available asset that can bring a high level of training to critically ill/injured patients. In these systems, there may be lower threshold for air medical dispatch.
      ii. 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.

iii. Disaster and mass casualty incidents offer important opportunities for air medical participation. These roles, too complex for detailed discussion here, are outlined elsewhere.

4. Clinical situations for **scene** triage to air transport (also known as "primary" air transport) are outlined below. 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).

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

i. General and mechanism considerations
   (a) Trauma Score <12
   (b) Unstable vital signs (*e.g.* hypotension or tachypnea)
   (c) Significant trauma in patients <12 years old, >55 years old, or pregnant patients
   (d) Multisystem injuries (*e.g.* long bone fractures in different extremities; injury to more than two body regions)
   (e) Ejection from vehicle
   (f) Pedestrian or cyclist struck by motor vehicle
   (g) Death in same passenger compartment as patient
   (h) Ground provider perception of significant damage to patient's passenger compartment
   (i) Penetrating trauma to the abdomen, pelvis, chest, neck, or head
   (j) Crush injury to the abdomen, chest, or head
   (k) Fall from significant height

ii. Neurologic considerations
   (a) Glasgow Coma Scale score <10
   (b) Deteriorating mental status
   (c) Skull fracture
   (d) Neurologic presentation suggestive of spinal cord injury

iii. Thoracic considerations
   (a) Major chest wall injury (*e.g.* flail chest)
   (b) Pneumothorax/hemothorax
   (c) Suspected cardiac injury

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

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

vi. Major burns
   (a) >20% body surface area
   (b) Involvement of face, head, hands, feet, or genitalia
   (c) Inhalational injury
(d) Electrical or chemical burns  
(e) Burns with associated injuries  

vii. Patients with near drowning injuries  

b. **Nontrauma:** At this time the literature support for primary air transport of noninjured patients is limited to logistical 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 diagnoses.

5. Clinical situations for air transport in **interfacility** transfers 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 nonfeasible.

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

i. 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.

ii. 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.

b. **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:

i. Acute coronary syndromes with time-critical need for urgent interventional therapy (e.g. cardiac catheterization, intra-aortic balloon pump placement, emergent cardiac surgery) unavailable at the referring center

ii. Cardiogenic shock (especially in presence of, or need for, ventricular assist devices or intra-aortic balloon pumps)

iii. Cardiac tamponade with impending hemodynamic compromise

iv. Mechanical cardiac disease (e.g. acute cardiac rupture, decompensating valvular heart disease)

c. **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:

i. Pretransport cardiac/respiratory arrest

ii. Requirement for continuous intravenous vasoactive medications or mechanical ventricular assist to maintain stable cardiac output

iii. Risk for airway deterioration (e.g. angioedema, epiglottitis)

iv. Acute pulmonary failure and/or requirement for sophisticated pulmonary intensive care (e.g. inverse-ratio ventilation) during transport

v. Severe poisoning or overdose requiring specialized toxicology services

vi. Urgent need for hyperbaric oxygen therapy (e.g. vascular gas embolism, necrotizing infectious process, carbon monoxide toxicity)

vii. Requirement for emergent dialysis

viii. Gastrointestinal hemorrhages with hemodynamic compromise

ix. Surgical emergencies such as fasciitis, aortic dissection or aneurysm, or extremity ischemia

x. Pediatric patients for whom referring facilities cannot provide required evaluation and/or therapy

d. **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:
i. Reasonable expectation that delivery of infant(s) may require obstetric or neonatal care beyond the capabilities of the referring hospital

ii. Active premature labor when estimated gestational age is <34 weeks or estimated fetal weight <2000 grams

iii. Severe pre-eclampsia or eclampsia

iv. 3rd trimester hemorrhage

v. Fetal hydrops

vi. Maternal medical conditions (e.g. heart disease, drug overdose, metabolic disturbances) exist, which may cause premature birth

vii. Severe predicted fetal heart disease

viii. Acute abdominal emergencies (i.e. likely to require surgery) when estimated gestational age is <34 weeks or estimated fetal weight <2000 grams

e. **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:

i. CNS hemorrhage

ii. Spinal cord compression by mass lesion

iii. Evolving ischemic stroke (i.e. potential candidate for lytic therapy)

iv. Status epilepticus

f. **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 vehicles into neonatal transport is to use them to rapidly get a stabilization/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:

i. Gestational age <30 weeks, body weight <2000 grams, or complicated neonatal course (e.g. perinatal cardiac/respiratory arrest, hemodynamic instability, sepsis, meningitis, metabolic derangement, temperature instability)

ii. Requirement for supplemental oxygen exceeding 60%, continuous positive airway pressure (CPAP), or mechanical ventilation

iii. Extrapulmonary air leak, interstitial emphysema, or pneumothorax

iv. Medical emergencies such as seizure activity, congestive heart failure, or disseminated intravascular coagulation

v. Surgical emergencies such as diaphragmatic hernia, necrotizing enterocolitis, abdominal wall defects, intussusception, suspected volvulus or congenital heart defects

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

i. **Transplant**
   (a) Patient with criteria for brain death and air transport is necessary for organ salvage
   (b) Organ and/or organ recipient requires air transport to the transplant center in order to maintain viability of time-critical transplant

ii. Search-and-rescue operations are generally outside the purview of 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.

iii. Patients known to be in cardiac arrest are rarely candidates for air medical transport.
   (a) A previous NAEMSP position paper has addressed situations in which resuscitation efforts should be ceased in the field for adult nontraumatic cardiac arrest victims. In such cases air transport should not be considered an alternative to discontinuing (futile) efforts at resuscitation.
   (b) 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 which 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, which 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)?
**SECTION X. SUMMARY & 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 U.S. 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.
SECTION XI. REFERENCES


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