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HELICOPTER EMS (HEMS)

OUTCOMES RESEARCH, COST-EFFECTIVENESS, & TRIAGE

(45 Pages)

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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). The author's 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. Perhaps the best example is a 2007 report from the independent Institute of Health Economics to 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."[1]

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[2] 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 – justified or not – HEMS will always be perceived as costly.

It is undoubtedly the case that air medical transport vehicles represent highly visible concentration of resources, and HEMS' presence continues to grow. A 2007 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.[3] 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).[4]

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 handout, "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.[5] For example, studies assessing prehospital intubation (ETI) have provided important – if unintended – insight into HEMS' salutary impact on outcome.[6, 7]

Many questions remain unanswered about HEMS. However, there *is* a body of evidence addressing HEMS' potential impacts in a variety of situations, that is often paid insufficient attention by those on either side of the HEMS debate. It is hoped that this discussion will help interested parties to better understand the evidence pertinent to the HEMS outcomes dialog.

SECTION II. OBJECTIVES AND HANDOUT CONTENTS

- Provide background on outcomes assessment methodology ***Section III***
- Introduce the literature assessing HEMS outcomes ***Section IV***
- Discuss possible HEMS benefits to patients ***Section V***
- Discuss possible HEMS benefits to EMS systems ***Section VI***
- Overview HEMS cost-benefit considerations ***Section VII***
- Address HEMS triage challenges ***Section VIII***
- Outline HEMS use recommendations ***Section IX***
- Summarize HEMS outcomes studies and cost-effective use ***Section X***
- Assemble listing of pertinent evidence/literature ***Section XI***

SECTION III. OUTCOMES ASSESSMENT IN HEMS

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, usually 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 follow.
     - The first and most important point is that HEMS safety is indeed a critical issue, and is in fact the industry's number one priority. Air medical transport safety has clearly deserved the attention focused on this issue in recent years, from experts such as Dr. Ira Blumen.[8]
     - While safety is critical, the overall low HEMS fatality rates render very low, patient risks from air transport. 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 report[9] 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, finds a decreasing crash rate and zero patient deaths during the study period.[10] Estimates for U.S. helicopter operations, based upon over two decades of data, report less than one patient death per 100,000 missions.[1] 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.[11]
     - 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."[12] U.S. authors have stated that just because there are "at least 6500 ambulance crashes a year" (and about 32 annual deaths) doesn't mean that ground EMS is unsafe – but it does mean that a rational examination of transport safety costs/risks and benefits must consider both air and ground accidents.[12] A recent study on adverse events in ground EMS[13] examined 2 years of national tort claims and identified a similar rate of deaths in prehospital ground transport. Ground EMS is clearly not "unsafe," but it is also true that HEMS risk should not be compared to a baseline of zero.
2. Secondary and surrogate outcome variables
   - 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.[14]
   - One group of secondary variables encountered in the medical literature deals with lengths of stay in various hospital departments (*e.g.* ICU stay). At least one HEMS study[15] 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 some evidence basis as being desirable 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.[16] Some secondary and surrogate endpoints may lack universal acceptance as impacting functional outcome, but others (*e.g.* hypoxemia in brain injured patients) are solidly evidence-based.
   - One 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 increas-

ing attention to this as an "outcome," preliminary work such as that by MacDonald *et al*[17] is of vital import. Assessment of patient safety and adverse events is in early stages, but HEMS investigators deserve credit for focusing on this measure.

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

1. The main problem consists of two closely linked parts: 1) Experts in many countries, even when they do not agree upon HEMS' effectiveness, are in agreement on the belief that a randomized controlled trial of HEMS *vs.* ground transport is not currently feasible, *and* 2) Since HEMS-triaged patients tend to be of higher acuity than ground-transported patients, outcomes analysis has to be acuity-adjusted; however there is no consistently reliable means of adjusting for acuity in HEMS-transported 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, leading 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. For example:
    a. An editorial[18] 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 to community hospitals include incorporation of HEMS into systems planning, as a necessary back-up in cases where urgent CABG is required.[19]
    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.[20] The American Stroke Association Task Force on Development of Stroke Systems[21] 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 cardiac and stroke 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.[22, 23]
    c. 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[24] 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 care centers in time to receive outcome-improving lytic therapy.[25, 26] Recently, 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.[27]

   The types of evidence found in expert and consensus opinion, and the sporadic evidence from 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, allowing 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 lar-

ger 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 scoring systems, such as GCS and TS, but one subject – TRISS – is a bit more complicated. Since 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 TRISS approach will be covered in some detail in this discussion. Given the understandable controversy around use of TRISS, it is noteworthy that, despite the its shortcomings there is no clearly preferable methodology; trauma systems experts writing as recently as 2005 have clearly stated that "TRISS is currently the gold standard for predicting outcomes in trauma patients."[28] (Furthermore, in mid-2006 a prominent trauma surgeon writing on triage, reiterated that the oft-criticized ISS is "the standard methodology for identifying severity of injury in the trauma patient"[29] and trauma systems specialists writing in 2007 reiterate the primacy of TRISS.[30]) Thus, some time spent learning TRISS fundamentals may be useful:
    a. For detailed explanation on the TRISS method, readers should refer to a separate, more definitive source such as that by Boyd *et al*.[31]
    b. TRISS incorporates physiologic (TS), anatomic (ISS), mechanism (blunt *vs.* penetrating) and age (55 years as dichotomous cutoff) covariates into a logistic regression model with mortality as the dependent variable.
    c. 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.
    d. Once the TRISS-predicted mortality has been calculated for the study population, the predicted mortality can then be compared to actual mortality.
    e. It is not necessary to delve into the details of logistic regression to intuit that for TRISS to work correctly, 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.
    f. Given the information in the above point (e), 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.[32]]
    g. If calculation of the M statistic denotes appropriateness of TRISS utilization, then a "W" statistic can be calculated; the W statistic estimates the number of lives saved for every 100 transports.
    h. In cases where further stratification is necessary, or in cases where M is less than .88, adjusted or standardized W statistics can be calculated.
    i. Finally, a *Z* statistic can be calculated, to test the null hypothesis of no difference between 0 and the calculated W.

   Once TRISS' applicability is confirmed, there are different mechanisms for using the methodology to assess outcomes. The most important difference in these mechanisms 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%.[30]

3. Use of either traditional (*e.g.* ISS) or TRISS scoring 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. Furthermore, as is the case with any study in which confounders are identified, the *identified* confounding variables are only part of the problem; the *unidentified* confounders (the existence likelihood of which increases when a single confounder is detected) are at least as problematic.

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 now an ongoing major randomized controlled trial of HEMS response (*vs.* ground paramedic care) for head injury in New South Wales, Australia. This trial has enrolled hundreds of subjects as of late 2008 (personal communication, Dr. Alan Garner, 10/21/08), and analysis is pending. Other than this fascinating trial, there are very few if any randomized data informing the HEMS debate. The types of studies are:

1. *Panel review* studies involve assessment of HEMS patients by groups of medical specialists, with retrospective ascertainment of potential benefits to the patient. An example of this design would be 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" (which is balanced by the disadvantage of bias) of this design is that it maximizes the ability for outcomes assessment to take into account the intangibles or other difficult-to-quantify advantages of HEMS or ground transport. Also, of all of the 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 divorce preconceptions about HEMS utility from the assignation of putative HEMS benefit in a given instance.
2. *Air vs. ground cohort* studies attempt to match acuity and other characteristics for HEMS and ground transported patients, and perform outcomes comparisons. An example of this type of study would be to assess outcomes in trauma patients stratified by RTS, accounting for the injury mechanism and for demographic factors. One pertinent study design would generate multiple 2×2 tables, each assessing HEMS *vs.* ground mortality for patients in a given stratum (*e.g.* TS grouping). The advantage of this design is that it employs 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 wide confidence intervals (low power) likely to cross the null value.
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 a "three-step" project which does the following: 1) compares HEMS-transported patients' actual to TRISS-predicted mortality, 2) compares ground-transported patients' actual to predicted mortality, and 3) tests the null hypothesis that mortality changes from predicted were similar in the air and ground cohorts. 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 – see above). 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 sometimes nebulous to those trying to interpret the paper. 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.[30]

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 HEMS transport of post-thrombolysis MI patients, which addressed the question of whether transport of such patients by air was associated with an increased risk of bleeding and other complications. An increasing body of evidence supports the 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.[33] 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 prospectively defined plans, but rather are assessments of what happens when HEMS availability in a given region changes. There are only a few studies of this type. The two studies published as full-length papers address (trauma) outcome in regions in which HEMS services, previously available, ceased to operate. In the first paper, methodological flaws of which preclude meaningful interpretation, investigators examined a Texas region's trauma mortality before and after HEMS discontinuation.[34] The second approach involved a situation in Oregon in which some, but not all, hospitals in the state 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).[35] The advantage of the natural experiment type of study lies in its potential to methodologically approximate the optimal (but most likely unachievable) study type – the randomized controlled trial. In actual implementation the natural experiment studies fall short of assuring such an ideal, but changes in HEMS availability over large geographical areas provide opportunities for useful population-based means of assessing HEMS utility. The weaknesses of the natural experiment design relate to the reality that the population must be studied both before and after HEMS discontinuation (*i.e.* the population of patients who *would have* been air-transported must be examined even if that means tracking mortality at referring institutions). Additionally, there is potential for confounding based upon regional care (*e.g.* an association between commitment to trauma care and willingness to bear costs of HEMS). A third natural experiment study has assessed changes in trauma mortality when HEMS availability changes in the *other* direction (*i.e.* helicopter coverage is added). Schiller *et al*[36] found that when an additional HEMS unit was added to a geographically isolated area of their trauma center catchment area, the number of HEMS-transported patients out of the region doubled and the regional trauma mortality decreased by 21% (OR .69, 95% CI 0.52-0.92). Another study (also published only in abstract form), assessed air-transported trauma patients versus those in whom HEMS was requested, but had to go to Level I care by ground. The findings of this Canadian group were that HEMS, as compared to ground transport to Level I care, saves a statistically significant 5.6 lives per 100 transports.[37]
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/commitment to trauma care) would be a major problem. However, preliminary work by the ADAMS (*A*tlas and *D*atabase of *A*ir *M*edical *S*ervices) 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).[38] The ADAMS data, like that from other trauma systems that clearly demonstrates mortality improvement in cases where HEMS transports to Level I centers,[39] parallels the reports of utility of HEMS in stroke[40] and cardiac[41] systems. It is nearly impossible to tease out the HEMS contribution from the other components of good system care. However, some systems studies[42] have concluded that HEMS utilization, given appropriate triage, 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, as recently as 2007 trauma sys-

tems experts were writing that "prospective randomized trials, however, are simply not feasible or ethical."[30]

7. In some cases, HEMS' impact 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 this also may be an advantage in that such studies tend to be executed by parties with no "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.[6] Editorialists[7] 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 2008 trauma systems study from Oregon,[43] 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."[43]
8. 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.[44]
   - With previously noted *caveats* about "expert opinion" as an evidence level, and acknowledging room for disagreement on the issue, 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.[45]
   - 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."[46]
   - 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[47] and airway management-associated physiology.[48] 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,[48] 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.[49] 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 hospital setting.[50] 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.[51]

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 works felt to most warrant inclusion in this handout. Many, but not all, of the papers are referenced elsewhere in this handout and are thus included in the References section. Those papers have been double-listed in this section, in an effort to provide the reader with a more complete, single-location listing of papers divided by diagnosis/patient population.

Overview

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 bene-

fits, warrants attention from anyone interested in optimizing evidence-based provision of out-of-hospital care. Definitive survey of all extant HEMS papers exceeds the scope of this discussion; the handout 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 Physicians (NAEMSP) set out in 2001 to update the organization's HEMS dispatch guidelines, there were no comprehensive HEMS outcomes reviews to aid in preparation of evidence-based recommendations. Accordingly, the NAEMSP Air Medical Committee generated two systematic reviews of the 1980-2000 HEMS outcomes literature (one review addressing nontrauma[52] and another trauma[53]), which were subsequently published in *Prehospital Emergency Care*. [These two articles were the foundation for the updated NAEMSP Guidelines for Air Medical Dispatch, which are discussed later in this handout 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.[54] Another overview addressing 2004-2006 literature is also found in *Prehospital Emergency Care*.[55]

Anyone interested in detailed listing of the HEMS outcomes literature may find the above-mentioned articles useful. Additionally, an update of articles relevant to scene trauma can be found in a review in *Emergency Medicine Practice*.[56] These articles, as well as an ongoing updating of HEMS outcomes literature maintained by the Air Medical Committee, can be obtained by e-mailing: Thomas.Stephen@MGH.Harvard.edu.

SELECTED ARTICLES WITH ANNOTATION

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

1. Lindbeck GH, Groopman DS, Powers RD. Aeromedical evacuation of rural victims of nontraumatic cardiac arrest. *Ann Emerg Med* 1993; 22: 1258-1262.

Note The authors, while highlighting the logistics advantages (*e.g.*, provision of 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.

2. Arfken CL, Shapiro MJ, Bessey PQ, Littenberg B. Effectiveness of helicopter versus ground ambulance services for interfacility transport. *J Trauma* 1998,45:785-790.

Note This study was conducted with statistical rigor, but it 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 a pooled acuity estimate), the authors correctly acknowledge a strong possibility of residual confounding due to air *vs.* ground acuity differences.

3. Werman HA, Falcone RA, Shaner S, et al. Helicopter transport of patients to tertiary care centers after cardiac arrest. *Am J Emerg Med* 1999,17:130-134.

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

- *TRAUMA – SCENE TRAUMA TRANSPORTS*

1. Baxt WG, Moody P. The impact of rotorcraft aeromedical emergency care service on trauma mortality. *JAMA* 1983; 249: 3047-3051.

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, though limited ground unit capabilities (*e.g.* use of esophageal obturator airways) limit the study's current applicability.

2. Baxt WG, Moody P, Cleveland HC, et al. Hospital-based rotorcraft aeromedical emergency care services and trauma mortality: A multicenter study. *Ann Emerg Med* 1985; 14: 859-864.

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 meant the HEMS contribution to good system performance was not isolated.

3. Schiller WR, Knox R, Zinnecker H, et al. Effect of helicopter transport of trauma victims on survival in an urban trauma center. *J Trauma* 1988; 28: 1127-1134.

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.

4. Nardi G, Massarutti D, Muzzi R, et al. Impact of emergency medical helicopter service on mortality for trauma in north-east Italy: A regional prospective audit. *Euro J Emerg Med* 1994; 1: 69-77.

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 and/or widely dispersed.

5. Nicholl JP, Brazier JE, Snooks HA. Effects of London helicopter emergency medical service on survival after trauma. *BMJ* 1995; 311: 217-222.

Note This oft-cited paper examined a subset of patients 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 odd outcomes assessment endpoints are among the paper's serious methodologic flaws. The study's outcomes validity is thrown into question by the subsequent finding (by Younge *et al*) of the inappropriateness of using standard TRISS in this population. In light of its serious limitations, the fact that this is one of the few published negative HEMS TRISS studies may be the main explanation for its frequent citation.

6. Cunningham P, Rutledge R, Baker CC, Clancy TV. A comparison of the association of helicopter and ground ambulance transport with the outcome of injury in trauma patients transported from the scene. *J Trauma* 1997; 43: 940-946.

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).

7. Younge PA, Coats TJ, Gurney D, Kirk CJC. Interpretation of the Ws statistic: Application to an integrated trauma system. *J Trauma* 1997; 43: 511-515.

Note This outstanding paper's deep methodological waters may account for the relative infrequency with which it is cited. The authors, determining that M statistic assessment meant uncorrected TRISS analysis was mathematically inappropriate for the London HEMS data (see Nicholl paper, reference 5 above), found HEMS resulted in about 4 excess survivors per 100 patients. Importantly, survival benefit could have been due to HEMS, receiving facility characteristics, or some combination.

8. Cocanour CS, Fischer RP, Ursic CM. Are scene flights for penetrating trauma justified? *J Trauma* 1997; 43: 83-86.

Note With methdodological 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.

9. Brathwaite CE, Rosko M, McDowell R, Gallagher J, Proenca J, Spott MA. A critical analysis of on-scene helicopter transport on survival in a statewide trauma system. *J Trauma* 1998; 45: 140-146.

Note In one of the largest, most methodologically rigorous papers in the HEMS literature, 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.

10. DiBartolomeo S, Sanson G, Nardi G, et al. Effects of 2 patterns of prehospital care on the outcome of

patients with severe head injury. *Arch Surg.* 2001; 136: 1293-1300.

Note This study, one of the best-written in the HEMS literature, 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).

11. Oppe S, DeCharro FT. The effect of medical care by a helicopter trauma team on the probability of survival and the quality of life of hospitalised victims. *Accident Analysis & Prevention*. 2001; 33: 129-138.

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 (Netherlands). The authors concluded there is significant HEMS benefit, and their data support their inference as applied to their own system. The study's external generalizability may be somewhat limited by the practice (appropriate for the Netherlands, but questionable for other settings) of HEMS crews' stabilizing patients who are subsequently transported by ground (often without HEMS crew attendance); for more information see comment for Frankema *et al* reference 14 below).

12. Chappell VL, Mileski WJ, Wolf SE, Gore DC. Impact of discontinuing a hospital-based air ambulance service on trauma patient outcomes. *J Trauma*. 2002; 52: 486-491.

Note This was the first study (published in full length form) addressing whether patient outcomes suffered when financial pressures resulted in HEMS service discontinuation. The authors did well to take on such a complicated study design, but the paper is severely limited by methodologic issues such as selection bias (*i.e.* lack of tracking outcomes for post-HEMS discontinuation era patients who were not transported to the regional trauma center). Mann *et al* (see reference 3, next section) basically executed the same study design, and came up with more reliable (and oppositely directed) results.

13. Shatney CH, Homan SJ, Sherck JP, Ho CC. The utility of helicopter transport of trauma patients from the injury scene in an urban trauma system. *J Trauma* 2002; 53: 817-822.

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. This 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).

14. Frankema SPG, Ringburg AN, Steyerberg EW, Edwards MJR, Schipper IB, van Vugt AB. Beneficial effect of helicopter emergency medical services on survival of severely injured patients. *Brit J Surg* 2004; 91: 1520-1526.

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).

15. Wang HE, Peitzman AB, Cassidy LD, Adelson PD, Yealy DM. Out-of-hospital endotracheal intubation and outcome after traumatic brain injury. *Ann Emerg Med* 2004; 44: 439-450.

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 clearly relevant to the HEMS debate (as noted in the accompanying editorial to the study which highlighted the fact that HEMS ETI improved outcome). As the authors note, 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.

16. Buntman AJ, Yeomans KA. The effect of air medical transport on survival after trauma in Johannesburg, South Africa. *South African Med J* 2005; 92: 807-811.

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 of the relevant confounders, strengthen the authors' findings. Interestingly, though the details of the calculation of HEMS benefit differ from some other TRISS studies, the result of just over 20% mortality reduction is generally in line with results from the extant HEMS literature.

17. Davis DP, Peay J, Serrano JA, Buono C, Vilke G, et al. The impact of aeromedical response to patients with moderate to severe traumatic brain injury. *Ann Emerg Med* 2005; 46: 115-122.

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 (indicting 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.

18. Davis DP, Stern J, Ochs M, et al. A follow-up analysis of factors associated with head-injury mortality after paramedic rapid sequence intubation. *J Trauma* 2005; 59: 486-490.

Note In a follow-up study to their earlier work assessing peri-ETI physiologic parameters, Davis *et al* here 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 or similar facility) with an odds ratio of 0.6 and 95% confidence interval 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.

19. Davis DP, Peay J, Good B, Sise MJ, et al. Air medical response to traumatic brain injury: A computer learning algorithm analysis. *J Trauma* 2008; 64: 889-897.

Note This fascinating and complex analysis used artificial neural network (ANN) 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.

- *ARTICLES FOCUSING ON INTERFACILITY TRAUMA TRANSPORTS*

1. Moylan JA, Fitzpatrick KT, Beyer AJ, Georgiade GS. Factors improving survival in multisystem trauma patients. *Ann Surg* 1988; 207: 679-685

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.

2. Boyd CR, Corse KM, Campbell RC. Emergency interhospital transport of the major trauma patient: Air versus ground. *J Trauma* 1989; 29: 789-794.

Note This TRISS study, led by one of those who understands TRISS best, found that HEMS clearly improved outcome when compared to ground transport control. Like other HEMS papers (*e.g.* that of Baxt *et al*) from the same time period, the passage of time has eroded the applicability of the study's results; for instance, only 8 of the 31 referring hospitals in the study had 24-hour physician coverage in the E.D.

3. Mann NC, Pinkney KA, Price DD, et al. Injury mortality following the loss of air medical support for rural interhospital transport. *Acad Emerg Med* 2002; 9: 694-698.

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.

4. Slater H, O'Mara MS, Goldfarb IW. Helicopter transportation of burn patients. *Burns*. 2002; 28: 70-72.

Note This group of burn surgeons determined that HEMS likely benefits some patients, but that the resource is overutilized. The authors' approach of discussing, with local ground ambulance providers, the real reasons for HEMS triage (*e.g.* based on ability to pay) represents an important contribution to the triage literature.

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

1. Moront M, Gotschall CS, Eichelberger MR. Helicopter transport of injured children: System effectiveness and triage criteria. *J Pediatr Surg* 1996; 31: 1183-1188.

Note In this well-conducted 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.

2. Thomas SH, Harrison TH, Buras WR, et al: Helicopter transport and blunt trauma outcome. *J Trauma.* 2002; 52: 136-145.

Note One of the 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.

3. Biewener A, Aschenbrenner U, Rammelt S, Grass R, Zwipp H. Impact of helicopter transport and hospital level on mortality of polytrauma patients. *J Trauma* 2004; 56: 94-98.

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 (mortality 22%) when compared to patients who were initially transported by ground to local hospitals and subsequently transported for Level I care (mortality 41%).

4. Larson JT, Dietrich AM, Abdessalam SF, Werman HA. Effective use of the air ambulance for pediatric trauma. *J Trauma* 2004; 56: 89-93.

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, apparently, in the vast ma-

jority of cases). The authors found no obvious benefit to immediate HEMS transport from trauma scenes, and argued that HEMS should probably be used for secondary transport after stabilization at referring hospitals. The authors acknowledged likelihood of residual confounding by severity since the two groups were distinctly different (*e.g.* scene transports were more likely MVC trauma and pedestrians struck). Well-performed 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 province-wide comparison using TRISS analysis. *Can J Surg* 2007; 50: 129-133.

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 at least 12) was found to improve mortality by 35% as compared with ground EMS. The difference in TRISS-derived *W* statistics for ground and air transport was 8.8, thus indicating HEMS (as compared to ground EMS) 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.

- *CARDIAC*

1. Fromm RE, Hoskins E, Cronin L, et al. Bleeding complications following initiation of thrombolytic therapy for acute myocardial infarction: A comparison of helicopter-transported and nontransported patients. *Ann Emerg Med* 1991; 20: 892-895.

Note This well-designed and executed study went far towards demonstrating the safety – at least for bleeding complications – of HEMS transport of patients after thrombolysis administration.

2. Straumann E, Yoon S, Naegeli B, et al. Hospital transfer for primary coronary angioplasty in high risk patients with acute myocardial infarction. *Heart* 1999;82:415-419.

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

3. Grines CL, Westerhausen DR, Grines LL, et al. A randomized trial of transfer for primary angioplasty versus on-site thrombolysis in patients with high-risk myocardial infarction. *J Amer Coll Cardiol* 2002; 39: 1713-1719.

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.

- *NEONATAL*

1. Pieper CH, Smith J, Kirsten GF, Malan P. The transport of neonates to an intensive care unit. *S Afr Med J* 1994;84:801-803.

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 to outcomes, the paper is nonetheless 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.

2. Berge SD, Berg-Utby C, Skogvoll E. Helicopter transport of sick neonates: A 14-year population-based study. *Acta Anesthesiol Scand* 2005; 49: 999-1003.

Note The authors of this study reported a large-scale, population-based (but 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.

3. Hon KE, Olsen H, Totapally B, Leung TF. Air versus ground transportation of artificially ventilated neonates: Comparative differences in selected cardiopulmonary parameters. *Pediatr Emerg Care* 2006; 22: 107-112.

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.

- *NEUROLOGIC*

1. Chalela JA, Kasner SE, Jauch EC, Pancioli AM. Safety of air medical transportation after tissue plasminogen activator administration in acute ischemic stroke. *Stroke* 1999,30:2366-2368.

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

2. Conroy MB, Rodriguez SU, Kimmel SE, Kasner SE. Helicopter transfer offers benefit to patients with acute stroke. *Stroke* 1999,30:2580-2584.

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.

3. Silliman SL, Quinn B, Huggett V, Merino J. Use of a field-to-stroke center helicopter transport program to extend thrombolytic therapy to rural residents. *Stroke* 2003; 34: 729-733.

Note This descriptive study addressed the contribution of HEMS to facilitation 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 stroke lysis 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.

- *OBSTETRIC*

1. Elliott JP, O'Keeffe DF, Freeman RK. Helicopter transportation of patients with obstetric emergencies in an urban area. *Am J Obset Gynecol* 1982,143:157-162.

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), that neonatal outcome for transported patients was similar to that for nontransported patients at the same center, and that many patients who would not have been transported by ground (because of refusal by referring physicians) were transported successfully by helicopter because of the rapid response time.

2. Van Hook JW, Leicht TG, Van Hook CL, et al. Aeromedical transfer of preterm labor patients. *Tex Med* 1998; 94: 88-90.

Note The primary utility of this study was as a "safety study" which demonstrated that HEMS transport of obstetric patients was not associated with significant outcomes detriments. The authors state that their study provides support for the view held "by most investigators," that maternal and fetal risks associated with HEMS transport are "at most, minimal."

3. Ohara M, Shimizu Y, Satoh H, et al. Safety and usefulness of emergency maternal transport using helicopter. *J Obstet Gynaecol Res* 2008; 34: 189-194.j

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).

- *VASCULAR*

1. Kent RB, Newman LB, Johnson RC, Carraway RP. Helicopter transport of ruptured abdominal aortic aneurysms. *Ala Med* 1989,58:13-14.

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

2. Shewakramani S, Thomas SH, Harrison TH, Gates JD. Air transport of patients with ruptured aortic aneurysms directly into operating rooms. *Prehosp Emerg Care* 2007; 11: 337-342.

Note This paper confirmed the feasibility, and likely utility, of HEMS crews' bypassing the receiving hospital ED 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). 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, 57, 58] As a dichotomous, easily ascertained endpoint, mortality can also be assessed with novel techniques. One example is the artificial neural network methodology reported by Davis *et al*, who 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).[5]
3. *Weaknesses* Mortality can be defined differently and somewhat arbitrarily (*e.g.* 30- or 60-day). 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 mechanism (*e.g.* streamlined prehospital times, improved airway management) for HEMS benefit.
4. *Conclusion* Whether or not HEMS results in any mortality improvement can be reasonably adjudicated based on a careful review of the applicable literature. There is reasonable basis upon which to make arguments that HEMS somehow improves survival in trauma patients

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 is 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])
4. *Conclusion* The literature review above includes some studies which address nonmortality endpoints such as quality-of-life and Glasgow neurological outcome score, but the fact remains that despite the at-

tractiveness of nonmortality endpoint assessment, methodological hurdles have prevented this technique from being as widely adopted as interested parties would like. 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 HEMS improves morbidity, writing that appropriate air medical utilization will result in "lives saved and disabilities prevented."[59]

C. Secondary endpoints

Secondary endpoints are myriad; the most useful are those with high clinical relevance. Examples are:

1. *Physiologic endpoints 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, 60] Investigators have addressed the intermediate 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 ETI) physiologic parameters such as end-tidal CO_2, which may be frequently disrupted during ground EMS ETI,[49] whereas they are much less so during HEMS ETI or even with HEMS transport post-ground ambulance ETI.[48, 51, 61, 62] Evidence demonstrating deleterious impact of peri-ETI physiologic disruptions (in head injury patients, at least) is sufficiently compelling that studies showing less such derangement in HEMS patients, should be considered as highly relevant to the outcomes debate.

2. *Pain control*

   After being neglected for too long as a priority for acute-care (and prehospital) medicine, the subject of pain care is finally receiving its due. Experts in prehospital care have written that pain care is a valid endpoint in and of itself.[14, 56, 63] Furthermore, the fact is that HEMS providers tend to be more diligent in assessing and treating pain, than ground EMS providers.[14, 47]

   While HEMS patients are different from ground EMS patients, the studies of patients with suspected isolated fractures result in substantial differences in analgesia rates (ranging from 1.8-12.5% for ground EMS, to over 90% for HEMS as outlined in detail in another review[56]). 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."[64]

   As HEMS researchers try and extend their outcomes assessments beyond mortality, pain assessment and care represent 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.[15] It is easy to argue that good pain care *can* be brought to bear by ground EMS (*i.e.* analgesia is allowed for 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 the following:

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.[65] Though there is little 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 an intervention will often be in the patient's best interests.

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

   In many regions, HEMS providers have pharmacological and procedural capabilities that outstrip the tools available to ground EMS. The differences in care capabilities can be dramatic. A report from the U.K. contended that patient outcomes were improved by performance of field thoracotomies.[44] The situation in the area served by Mayo Clinic in Minnesota may be more 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.[4] Especially in rural areas, the only

prehospital care available may be BLS level.[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.[4] Thus, HEMS is an important mechanism for getting to the patient, medical crews that bring important expertise to both trauma scenes and small community hospitals. For example, HEMS 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.[4, 6, 51, 60, 66-69] It seems likely that poor results from ground ETI (as assisted by neuromuscular blockade) are related in part to provider inexperience and differences in training for HEMS as compared to most ground providers.[4, 6, 70, 71] As another example, critical care transport teams (that use both helicopter and ground vehicles) have reported sophisticated ventilatory and other advantages accrued with use of $ETCO_2$ monitoring in pediatric and adult patients.[4, 61, 72]

As mentioned previously, there is increasing evidence that better airway management skills are responsible for better outcomes in at least some patient groups. For patients with head injury, there are now large-scale studies identifying markedly improved outcome for HEMS patients, as compared to ground ambulance transports, for those undergoing prehospital ETI.[6, 51, 60] It is unrealistic to expect that the airway management expertise possessed by busy HEMS providers can be easily attained by practitioners with less experience and less rigorous training.[70]

In addition to ETI capabilities, HEMS crews operate with benefit of experience dealing with critically ill and injured patients; the HEMS crews may in fact have more comfort with high-acuity patients than even physicians at a referring hospital.[4] 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.[73] There has been little concrete correlation between such findings and mortality, but the common-sense implications are difficult to refute.

3. *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.[74] Shorter transport duration would seemingly be a "given" for HEMS use, but ever since early HEMS studies (*e.g.* Baxt *et al*)[75] found that HEMS did not save time, this supposed HEMS benefit has been subject to debate. Studies conducted from regions as disparate as California and the Netherlands clearly demonstrate HEMS mortality benefit, yet find similar scene-to-trauma center times for ground and HEMS transports.[76, 77] One study from a well-developed HEMS and trauma system in the Netherlands finds that (physician-staffed) HEMS crews' scene times are about 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).[78] The prolongation in scene times was accounted for by patient acuity and casemix, and adjusted analysis showed no effect of on-scene time on survival (OR 1.0, $p = .89$).[78]

The consideration of urban 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 since distances are short. On the other hand, such areas tend to be particularly prone to traffic congestion and transport delays (depending on the time of day). Since most studies focusing on transport times tend to have the times for one vehicle type or the other "estimated" it is fairly 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.

Transport time is, in some cases, potentially life-saving – the premise that faster transport improves trauma mortality is widely accepted based upon available evidence. Authors focusing on logistics studies support the notion that time to definitive care is an appropriate primary endpoint, writing that "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."[79] The authors of a Pennsylvania trauma registry-based head injury study, in noting that HEMS was associated with improved survival and function outcome, noted that that their results could have "simply reflected the effect of [faster] transport time to trauma center"[6] Furthermore, the impact of logistics on trauma mortality has been argued in a 2005 *JAMA* study which found that HEMS represented the *only* mechanism by which 27% of the U.S. population had timely Level I or II trauma center access (within an hour of receipt of emergency call).[80] 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.[80] 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 a recent large-scale study finding that Level I trauma care results in a distinct outcomes benefit as compared to other levels of trauma care;[81] for at least a quarter of the US population, helicopters thus represent the only mechanism for rapidly accessing life-saving care for injuries.

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 handout and elsewhere, that demonstrates HEMS utility for secondary (interfacility) transport of trauma patients. Loss of HEMS availability has been recognized as a potentially important factor causing increased trauma mortality in patients presenting to non-Level I centers.[82]

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.[83] The use of air medical resources to rapidly move patients to specialized centers is gaining increasing attention in part because of the ever-growing realization that "time is myocardium", "time is brain tissue", etc.[83-85]

In terms of cardiac patient tranports 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.[86, 87] 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.[88] In fact, 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.[89] Additionally, evidence is accumulating that community hospital lytic therapy for ischemic stroke is reliant upon a technology – CT scanning – that has major problems as currently used.

Stroke represents another diagnosis that is now understood to be time-critical. Considered in one easily understood way, each hour of ischemic stroke results in neuronal damage approximating 3.6 years of normal aging.[85] 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.[90] The increasing awareness that advanced imaging (*e.g.* diffusion-weighted MRI) optimizes accuracy and safety, combined with the current (and likely near-future) lack of round-the-clock availability of such imaging,[90] has high potential to translate into a major role for early and rapid HEMS transport for stroke.

Sepsis, a long-recognized disease process, has not generally been considered "time-critical." This view has changed, with the advent of studies demonstrating improved outcome associated with goal-directed therapy. Recent reviews of sepsis care have emphasized the importance of the six-hour goal for institution of high-level sepsis care.[91] 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 (and fetal) outcome benefits for high-risk obstetrics transports that simply would not have occurred (due to physician unwillingness to have prolonged transport times) in the absence of air transport.[92] More recently, a group from Florida[40] 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.[93, 94]

One approach currently in investigative use in Boston incorporates the twin novelty of 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.[41] 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 catheterization 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.[95] There is growing recognition of importance of transporting ST-elevation myocardial infarction (STEMI) patients for primary percutaneous intervention (PCI). For example, a consortium U.S. panel of U.S. EMS medical directors has recently identified as an evidence-based benchmark for quality prehospital care, the transport of STEMI patients to primary PCI within 90-minutes of EKG diagnosis.[96] 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.[97] It is clear that, for some regions and their patients, HEMS provides a vital capability to meet this benchmark.

The authors of a logistics study from the University of Wisconsin[22] 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-trauma center time." Even if a HEMS service takes longer than local ground units to respond to a community hospital patient requiring transport to a tertiary care center, in most cases the actual time spent in patient transport can be 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 performance, the actual out-of-hospital time saved by HEMS use averaged 20 minutes (58 minutes for HEMS *vs.* 78 minutes for ground transport).[79] In some patients – especially those who are in tenuous condition or who may require difficult interventions in the event of deterioration – the 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 the 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.[98]

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 that bypassing community hospitals in favor of direct transport to larger, higher-volume centers (and perhaps more capabilities such as primary percutaneous coronary intervention). 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.[29] In fact, there is strong evidence basis to suggest that, for blunt trauma patients, bypassing community hospitals (including HEMS-executed bypass) in favor of direct transport to Level I trauma centers has a significant and positive impact on outcome.[99-105] 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."[102] More recent 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.[106]

As a general rule, use of HEMS for direct transport to tertiary care is commonly used for trauma patients and less commonly used for other patient categories. Data from the Centers for Disease Control and elsewhere has confirmed that, for the general population of injured patients, trauma center care (*i.e.* appropriate triage) results in substantially reduced mortality.[81 107] 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.[108] 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).[109] It is also 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.[110-113] 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.[114, 115] 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.[105] 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."[114]

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).[26, 65, 116] 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.[116] A recent preliminary report on simultaneous HEMS dispatch and tertiary care hospital cardiac cath lab activation, by ground prehospital providers diagnosing STEMI during transport to a community hospital, found the time at the referring hospital was reduced from 79 to 31 minutes.[117] 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.[118]

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 report[119] 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.[40] The same logic holds true for injured patients undergoing air transport to Level I centers.[39] 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

It goes without saying that if HEMS is associated with mortality (or significant morbidity) improvement, then it benefits a regional EMS system to have access to such a service. Whether the EMS region is dealing with increased interfacility transports as a result of implementation of "inclusive" trauma systems[103] or more frequent HEMS use for stroke patients, air medical transport clearly has a vital role in regionalization of care. While patient-centered thinking should be paramount, some logistic and economic considerations represent very important potential utilities for HEMS services.

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[4] has written that "This kind of coverage, in many areas of the country, provides advanced care where it is not otherwise available." 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 analysis has suggested 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. Recent literature suggests that even with ma-

jor emphasis on training, some ground EMS systems have had efficacy difficulties when neuromuscular blockade-assisted ETI protocols were instituted. In at least two regions, neuromuscular blockade-assisted intubation by ground EMS was sufficiently problematic that the practice was discontinued. Contrasting this with the 95-98% intubation success rates regularly reported by HEMS services, HEMS proponents make sound arguments that HEMS is a reasonable means for a given EMS region to provide a high level of care to a large area.

HEMS may offer benefits even to patients already at (smaller) hospitals.[33] This is most likely true in rural settings in which local facilities may be staffed by individuals with relatively little experience with trauma or other critical illnesses.[30] In trauma, for instance, the lack of ready availability of surgical subspecialists (*e.g.* neurosurgeons) is translating to an increasing inability of non-Level I centers to care for injured patients.[110] Trauma triage experts have clearly 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.[110]

The issue of regionalization of trauma care is well-known to acute care physicians, but recent data have clarified the importance of capabilities to get injured patients to a trauma center. In fact, a 2008 consortium panel of U.S. metropolitan EMS medical directors emphasized the importance of transporting patients for trauma center care if they have ISS>15 (number needed to treat to save one life: 11).[96] As trauma systems mature, there is obviously a role for HEMS in the occasional transport of patients to insure 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-level care to geographically remote areas, HEMS can offer a means for relatively isolated areas to get patients to tertiary care centers without necessitating removal of scarce ground ALS resources from the region. At least one paper[120] has specifically identified that one major reason rural areas use HEMS is that 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 patients with noncritical illness or injury may not be in the best interest of the system as a whole – some regions have come to rely on HEMS as a means to assure they will not lose ALS coverage for hours, every time a patient requires ALS-level transport to a distant receiving hospital. As an added benefit, the use of helicopters for longer-distance transports of critical patients can reduce the risks associated with prolonged red-lights-and-siren ground EMS transports.[4]

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.

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. It could be argued that 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 (*e.g.* trauma), probable (*e.g.* acute coronary syndromes for cath), or possible (*e.g.* acute stroke patients for lysis) 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.[81, 82, 121-123] 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).[104] Emerging literature makes compelling arguments, from perspectives of both outcomes and cost (*e.g.* preventing dual workups), for direct transport of pediatric trauma patients to specialized centers.[124]

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.

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 "legs" can often bring relatively 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,[125] 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 often 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),[102] 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,[126] 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.[125] 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.[82]

F. Ability to perform unusual and *ad hoc* activities

While no one questions the flexibility and capabilities of ground EMS units, the nature of the helicopter lends itself to utility in unusual circumstances. For example, in the unusual 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.[45] The utility of HEMS in disaster and mass casualty incidents is well-described.[125] In fact, during the London subway bombings of 2005, the London HEMS aircraft flew at least 25 missions – none of them patient transports, but rather transportation of medical care teams to incident sites. Given the traffic situation in London at that time, the HEMS was judged to be a vital part of the emergency response (personal communication, Dr. David Baker of the UK's Health Protection Agency, 21 June 2007).

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.[127]

In addition to transport people, helicopters have been occasionally used to rapidly transport vital supplies or equipment (*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.[83]

SECTION VII. INTRODUCTION TO HEMS COST-BENEFIT CONSIDERATIONS

It is a truism that if HEMS is associated with mortality (or significant morbidity) improvement, then it benefits a regional healthcare system to have access to such a service. Furthermore, 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. Even the most ardent HEMS critics concede that helicopter utilization 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. Those who have delved into the detailed economic analysis required for truly rigorous cost-benefit calculations have noted the difficulties in apparently simple maneuvers such as assigning value to human life.[128] Fortunately, some rigorous and independent analysis of cost and benefit data has been conducted. A previously mentioned 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."[1] Detailed reproduction of economic analysis is beyond the scope of this discussion, but following is a brief overview of some of the data underlying conclusions about HEMS costs and benefits.

Some of the most rigorous investigations of cost-effectiveness come from Scandinavia. One well-done 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."[128] 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.[129]

The Norwegians' estimate (actually 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.[130] 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.

A. Cost-effectiveness

The quantitative approach to assessment of costs and benefits generally incorporates analysis of cost-effectiveness. This approach ties a specific dollar cost to a specific measure of "benefit" where benefit is usually 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" – indeed, some investigators use negative numbers for some conditions – but the QALY unit remains a broadly accepted metric.[131]

After one performs a cost-benefit calculation (*i.e.* in dollars per QALY), 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. Unfortunately, the true situation is far more complicated, since the costs should be applied for a given regional system – one in which a relatively few air medical assets provide advanced level care (and usually more rapid transport capability) that would require a large fleet of ground EMS units. Exploration of this "regional view" has resulted in at least one economic study concluding that HEMS is *less* expensive than development of a wide-ranging fleet of ground EMS vehicles.[2] Complex cost considerations are beyond the scope of this discussion, but there has been excellent work recently, that paints a picture of the myriad factors that should be considered when trying to adjudicate true costs of EMS systems and components.[132] 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)[92] or would not occur within a critical time window (as for stroke or cardiac transports).[41, 93] There is no ground transport option capable of rapidly moving through rush-hour traffic in Los Angeles;[92] there is no realistic surface vehicle option for stroke or cardiac patients on Martha's Vineyard (an island off coastal Massachusetts) who need timely transport to neuro-interventional or cardiac cath suites.[93] 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,[80] it becomes obvious that *some* form of HEMS is a "must-have" for some U.S. EMS regions. The direct bearing on the cost-effectiveness calculations is not hard to see: If a region must have air medical assets for some group – however small – then perhaps it's appropriate to spread the "overhead" costs across all transported patients? Put another way, if eastern 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."

Increasing amounts of data show that the best mechanism for improving trauma mortality is to get significantly injured patients directly to a tertiary trauma center.[81, 104] 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 suggest that the extra hospital "stop" adds about $700 to per-patient transport expenditure,[133] and an equivalent cost (at least) in repetition of laboratory and radiology evaluation.[134] 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).[133] 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 is fair to point out that the issues are sufficiently complex that one cannot simply say "helicopters are 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. However, there *is* guiding literature, and it is informative. In fact, the reader may be forgiven for some surprise (given the infrequency with which the relevant studies are cited) at 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.[135] 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.[107] 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.[107] Other investigators have executed economic analyses and concluded that HEMS reponse to the scene, with direct transport to trauma centers, is beneficial and also cost-effective.[133]

While the reader is referred to other sources[56, 136] for detailed explanation, a general estimate of cost per life-year saved for adult trauma transports can be calculated to be in the range of $2500 given the industry-standard transport cost and a *W* estimate (see TRISS discussion above) of 5; the cost/life-year rises to $9,700 if *W* is set at 1. (This approach works for pediatrics as well; the survivors' greater expected longevity would offset the lower estimate for *W*.)

How does an estimated cost per saved life-year of $2500-$9700 compare with the cost-benefit ratios of other medical interventions? In their HEMS cost-benefit paper, Gearhart *et al*[136] report HEMS was associated with less cost per life-year saved than the following interventions:

Intervention	Cost per life-year saved
• neonatal ICU for birth weights 500-999g	$18,000
• median for 310 medical interventions	$19,000
• 3-vessel coronary bypass for severe angina	$23,000
• thrombolytic therapy for acute MI	$32,678
• prophylactic AZT after needlestick injury	$41,000

The above numbers are a bit dated (1996), and that study did not assess *quality-adjusted* life years (QALYs), but the Gearhart data gives a reasonable overview of the context in which HEMS costs should be considered as compared to other, contemporaneously calculated, medical costs. If costs are considered in current dollars, HEMS continues to fare well. For instance, a recent *New England Journal of Medicine* article[137] addressing cost-benefit of HIV screening averred that a cost-effectiveness of $42,000 per quality-adjusted life year was "well within the range of that of other commonly accepted health care interventions." A healthcare economist writing in the *New England Journal of Medicine* in 2007, has rated a cost per QALY of $11,000 as "extremely favorable."[138] 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.[131, 139, 140] One 2007 trauma study defined $50,000 per QALY as a benchmark defining acceptability,[141] although another 2007 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.[142]

Interestingly, the estimates for cost-effectiveness are generally consistent across different countries. In a report prepared for the British government's Department of Health,[143] 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.

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.[2] (That analysis is predicated, by the way, upon an assumption that the skills attained by highly trained air medical crews and practiced daily, would not be diluted if HEMS crews were replaced by a fleet of ground ambulances.) Overall, while data are necessarily suboptimal, it seems fair to conclude that in terms of cost per life-year saved, HEMS (at $2454) is probably less expensive, and at least in the ballpark range of, ground EMS costs ($8886).[2, 144] Unfortunately, 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.[145]

As for costs associated with the "post-EMS" phase, there are data addressing the cost-effectiveness of trauma centers. Available evidence indicates that the costs per life saved (not costs per life-year) incurred in establishing a Level I trauma center are $84,000.[146]

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. One of the best examples of such work is that of Silbergleit *et al*,[147] who demonstrated HEMS cost-effectiveness for patients with 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. Nonetheless, 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 (evidence-driven) transport process that involves both air and ground modalities.[148]

SECTION VIII. OPTIMIZING HEMS UTILIZATION: AN OVERVIEW OF TRIAGE

Like 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.[1] For one thing, in the realm of nontrauma the development of evidence-based HEMS triage criteria is limited by a dearth of applicable high-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 traumatologist writing in a U.S. government agency (NHTSA) report:

> "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."[59]

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."[59] 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.[149, 150] 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.

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, modern medicine does not and should 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 a cranial computed tomography scan is negative (and how many EDs reach even a 5% rate of clinically relevant positive findings on their head CTs?). There are ongoing efforts to reduce unnecessary cranial CT, but the issue of such imaging "overutilization" has not been characterized by the clamor associated with the HEMS debate. Consideration of the issue of HEMS overutilization must be equally 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 *under*triage is a well-recognized cause of increased morbidity and mortality in the trauma population.[110] 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.[82, 103, 110] 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.[110]

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%."[151] In fact, the overtriage rate most commonly accepted in systems studies is about 50%, but studies report trauma systems overtriage rates ranging to 90%.[42, 152] This level of overtriage and undertriage has been cited by prominent traumatologists who have particular expertise in prehospital care systems.[29] 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.[153]

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 assignation, based upon estimation of travel times, of theoretical ground EMS times. This approach (as used by Shatney *et al*)[154] 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 by 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.[45] Furthermore, the work of Svenson *et al*[22] 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" have tended to focus far more attention on scene, as compared to interfacility, transports. One of the largest recent reviews of HEMS overutilization[155] discarded outcomes studies incorporating interfacility transports, an approach that only illuminates part of the story. Recent assessment of over 10,000 injured patients undergoing initial evaluation at 43 non-trauma center community/rural hospitals in Oregon[156] 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 be the major trigger for HEMS dispatch. For instance, some have written that ground transport times of at least 30 minutes are consistent with need for HEMS transport for head trauma patients.[157] Others have written[135] that simultaneous HEMS and ground EMS dispatch becomes time-beneficial when patients are at least 10 miles from the receiving trauma center, but they point out that 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.[135]

Other investigators have drawn different conclusions, illustrating the heterogeneity of logistics situations in varying regions. For instance, use of "autolaunch" (*i.e.* HEMS dispatch based upon reports by lay passersby, before arrival of law enforcement or first responders on the scene) in Minnesota, while associated with only a 21% mission completion rate, was found to have favorable cost-benefit analysis.[4] 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.[4]

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.[158] 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).[79] 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).[159] 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 the previously mentioned Ontario study and also in other settings, time benefits of air transport are optimal only if the referring and receiving hospitals have ready access to helipads.[160]

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 simply get to patients for rescue, is at least as important as any advanced medical care the HEMS crews render.[161]

The logistics of triage are complicated, as has been pointed out by trauma systems experts.[42] 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.[42] 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

The authors of one discussion addressing triage[159] conclude that "The decision to use a helicopter is not straightforward, and a number of important geographical, physiological, and pathological 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 more difficult to do, is be able to use available evidence to support any overhaul of 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[155] 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'[155] mention of using GCS and heart rate (in the manner of a speculation by Moront *et al*[162]) manages to combine a poorly sensitive variable (GCS) with a parameter (heart rate) that is quite nonspecific. Such an approach has demon-

strated nonviability in the trauma triage literature (see Henry *et al*[114], 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.[82, 103, 152, 163-168] As Hedges wrote in mid-2006, "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."[103] (In fact, just as paramedic judgment remains an important component with demonstrated potential to improve prehospital triage,[103] "physician discretion" remains an important part of secondary/physician triage.[82])

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.[153] 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%.[169] 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%.[170] 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%.[136]

The population-based New York trauma registry analyses reported by Henry *et al* [114] 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* [114] 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 also reiterated the importance of utilizing "other" criteria such as age>55, cardiac and respiratory disease history, coagulopathy, Type I diabetes, cirrhosis, and morbid obesity.[114]

More recently, a 2008 study in Australia finds that even the most seasoned paramedics (those staffing air medical services) were able to achieve acceptable triage sensitivities only with high levels of overtriage.[152] 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%.[152]

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.[171, 172] Should triage rules require manual blood pressure assessment? Given the known association[173, 174] between injury severity and even a single episode of field hypotension (*i.e*. with normal blood pressure upon trauma center arrival), the prehospital evaluation of 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.[114] 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."[171] 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.[162, 171] In fact, it is well known that referring physicians (like prehospital providers), are much quicker to activate transport of pediatric patients.[175] Perhaps the extra precaution in children – who represent an enormous potential for trauma systems' impact on quality-adjusted life-years – is wasteful, and perhaps 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."[176]

A detailed discussion of trauma triage can be found in *Prehospital Emergency Care*'s July-September 2006 issue. 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."[107] Some high points include the following areas in which there is solid evidence: 1) rapid transport to trauma centers saves lives;[81] 2) much of the U.S. population can *only* reach Level I centers in timely fashion by HEMS;[22, 80] and 3) trauma transport decision-making is heterogeneous and inconsistent even when physicians (at community/rural hospitals) are doing the triage.[82, 156] 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.[103] 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.[177] Until ongoing efforts to refine trauma center triage further illuminate triage issues from system and HEMS perspectives,[103, 107] 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.[46, 155] 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 clearly an inferior option. Along these lines, the National Association of EMS Physicians generated updated Guidelines for Air Medical Dispatch in 2003[178] (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.[110]

As a final point on HEMS utilization before listing the NAEMSP Guidelines, it should be emphasized that the employment of these or any other Guidelines should be part of a regionwide, cooperative process that incorporates all affected parties (from EMS to community hospitals to receiving centers). Furthermore, the *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.

SECTION IX. NAEMSP 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 (for examples: 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 nontrauma 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 sys-

tems 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, hemodyamic 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[15] 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 which 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 not available 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. However, the 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 these guidelines are adhered to.

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