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Helicopter EMS beyond Trauma: Utilization of Air Transport for Non-Trauma Conditions

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ABSTRACT

Helicopter Emergency Medical Services (HEMS) use in civilian medical transport has its roots in the use of rotor-wing trauma transport in the military setting. Much of the literature and evidence based on the use of HEMS is therefore related to scene and interfacility transport of injured patients. Regionalization of care and increased understanding of time-criticality of various non-trauma conditions has contributed to growing utilization of HEMS for non-trauma conditions over recent decades. It is common for HEMS to be utilized for a variety of non-trauma situations ranging from neonatal and obstetrics transports to cardiac and stroke transports. The purpose of this review is to overview the use of HEMS for non-trauma, focusing on situations in which there is evidence addressing possible HEMS utility.

Keywords: Helicopter Emergency Medical Services; Air Medical Transport; Prehospital Care

1. Introduction

This discussion strives to overview evidence addressing benefits accrued by utilization of helicopter EMS (HEMS) for non-trauma patients. The primary goal will be to analyze HEMS literature to describe, qualitatively and quantitatively, potential benefits of air medical transport for medical and non-trauma populations.

The discussion commences with background information that is provided to facilitate interpretation of HEMS studies. Next, the non-trauma HEMS outcomes in literature are introduced with divisions by diagnostic category. The review concludes with the summary and suggested directions for future investigation.

The HEMS outcome debate's longevity and vigor constitute sufficient impetus for evidence-based exploration of whether there is benefit to air medical transport. Fortunately, some detailed exploration of existing data has been executed. One excellent example is a report in 2007 from the independent Institute of Health Economics, prepared for the Canadian health ministry in Alberta. These authors, after reviewing all available studies from the year 2000, concluded: "Overall, patients transported by helicopter showed a benefit in terms of survival, time interval to reach the healthcare facility, time interval to definite treatment, better results, or a benefit in general" [1].

The Alberta publication addressed a variety of patient types, but most direct HEMS outcomes' information (including the only Cochrane review of HEMS outcomes) addresses HEMS use for injured patients [2]. Thus, there appears to be a relative paucity of information overviewing HEMS use for non-trauma.

Why a review article on HEMS non-trauma uses? Perhaps the most important reason is that, as to the maturity of the applicable evidence, air medical transport is broadly employed for non-trauma cases. The National Association of EMS Physicians (NAEMSP) Guidelines for HEMS use includes a variety of recommendations (although acknowledging lack of solid evidence base) for HEMS dispatch for non-trauma [3]. Furthermore, as long ago as 2003 a *Chest* editorial [4] observed that "In many communities, emergency air medical systems have become an integral part of the practice of cardiology and critical care medicine." The *Chest* authors 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." There is also a long history of HEMS use for non-trauma surgical cases. An article from a quarter-century ago described the use of air transport for patients with ruptured aortic aneurysm [5].

If HEMS are going to be used for non-trauma, then it is important to assess and optimize resource use by identifying cases in which benefit is most likely to occur. This is important because of the highly visible concentration of costs that are present with helicopters. Some investigators have assessed regional costs of HEMS to be no higher than those associated with response-time-equivalent (multivehicle) ground critical care coverage [6]. However, the perception is (and likely will long be) that air medical transport is expensive. Use of an expensive resource should be accompanied by an assessment of justification for such use.

Since few argue that HEMS benefit is always predicated on time and logistics, consideration of HEMS outcomes' evidence touches upon the broader subject of levels of care beyond advanced life support (ALS) in the prehospital setting. Thus, this arena will also be discussed herein.

For purposes of consistency within this review, "prehospital" is interchangeable with "out-of-hospital" in order to encompass both scene and interfacility transports. HEMS crews' extended practice scope, even in the US where crews often do not include physicians, facilitates consideration of benefits to advanced care [7].

While most non-trauma HEMS use falls within the realm of secondary (interfacility) transport, the items in this review are not limited in scope to interhospital transfers. Suggestion of potentially growing indications for HEMS "scene" transports of non-injured patients is provided by an evolving literature describing significant utility to direct HEMS response to patients such as those with acute coronary syndrome (ACS) or ischemic stroke [8-11].

Many questions remain unanswered about HEMS. However, there is a body of evidence addressing HEMS' potential outcome impacts, which is often paid insufficient attention. This discussion's goal is to provide information on non-trauma HEMS use, in order to aid interested parties to understand the evidence pertinent to the outcomes dialogue. It is hoped that the review will assist those physicians and systems planners who are pursuing appropriate and judicious employment of potentially life-saving HEMS resources.

2. Outcomes Assessment in HEMS

This section covers the approach to considering HEMS' impact for non-trauma indications. It's necessary for planners to incorporate HEMS "outcomes" on patients, EMS systems, and regionalized care networks. The subject of mechanics of outcomes assessment in HEMS has been addressed in detail in a 2012 review [12]. Highlights and recent advancements will be covered in this section.

One important recent development is a joint position statement promulgated by the Air Medical Physicians Association (AMPA), the National Association of EMS Physicians (NAEMSP), the American College of Emergency Physicians (ACEP), and the American Academy of Emergency Medicine (AAEM) [13]. The position statement, published at the end of 2013, includes some important consensus ideas about the state of the art with HEMS; the document also gives directions for forward movement of HEMS development. Among the important points made in the consensus statement are some with relevance to this review. For instance, the consensus statement avers that for many time-critical situations, particularly those for which there is time-windowed therapy, the measurement of HEMS' impact on outcome is best focused on delineating the amount of time saved by air transport [13].

Before moving to other outcomes, a note on HEMS safety is appropriate. The recent joint organizational consensus statement includes the need to emphasize safety and also the importance of separating aviation decision-making from the clinical arena [13]. The subject of aviation safety and HEMS' flight-related risks is so important that a even a cursory overview does not serve. Interested readers are directed to the work of experts such as Blumen from the University of Chicago [14].

Direct patient outcomes benefits are most important. If there are none, then there is low likelihood that HEMS use is appropriate or cost-beneficial when considered on a system basis. For patient-centered considerations, mortality is the most important and most commonly studied endpoint in HEMS trauma studies [12]. For non-injured patients, however, there are few easily applied scales to adjust for the inherent acuity differences between ground and air transported patients. Thus, direct assessment of mortality is quite difficult since analysis cannot control for the unadjusted (higher) mortality risk of the air transport cohort. Therefore, for non-trauma cases HEMS' patient benefits tend to be measured indirectly, via endpoints that are either secondary (e.g. myocardial muscle salvage) [15] or surrogate (e.g. time-to-cath lab) [16]. Fortunately, for at least two commonly transported diagnostic populations (cardiac and stroke), there are objective data that allow direct correlation of time savings to improved mortality and morbidity [17,18].

While patient-centered outcomes are of course most important, other "outcomes benefits" (e.g. systems benefits) may also contribute to potential justification for including HEMS in a system. These benefits are complementary to direct patient benefit. HEMS can allow for improved regional performance in getting non-trauma patients to definitive care such as provided by stroke centers, cardiac catheterization labs, or operating rooms [19,20].

In the absence of randomized controlled trials-generally viewed as nonfeasible for HEMS research [13,21] one approach for non-trauma is to demonstrate that use of HEMS allows for "far-away" patients to achieve the same good outcomes as are achieved for those who live near hospitals. This approach has been executed for cardiac [22], obstetric [23], and neonatal [24] patient populations, with findings that HEMS allows for outcomes that are as good as those seen in patients presenting primarily to tertiary care centers.

The remainder of this review addresses HEMS use for various non-trauma diagnoses. There are varying depths of evidence for various utilizations, but the goal of the discussion is to include all non-trauma situations for which there are at least some relevant studies. The most data are available for cardiac patients, with stroke following. Sparser but still directly relevant evidence is available for non-trauma surgical cases, pediatrics, and obstetrics; these populations are addressed in order in the following sections of this review.

3. HEMS for Cardiac Patients

The primary utilization of HEMS for cardiac cases is in the setting of ACS, most notably ST-elevation myocardial infarction (STEMI) needing percutaneous coronary intervention (PCI). Other diagnoses are certainly important, as outlined in the NAEMSP guidelines for helicopter use [3], but air transport's logistics advantages have obvious potential for frequent use in time-critical STEMI.

3.1. Patient Safety

In addition to the obvious and overriding importance of aviation safety (outside the scope of this review), lie questions about patients' medical safety during air transport. Early data [25] indicating catecholamine rise during air medical transport suffered from lack of appropriate ground EMS controls, and sympathetic "surge" never became an area of concern for HEMS. However, the early questions did prompt consideration of other potential dangers associated with air transport. The major issues to be considered were electrical and vibrational.

Electrical considerations were focused on the ability of pacemakers to function properly in the aviation setting. In considering theoretical and practical concerns (e.g. pacemaker separation of patients' intrinsic electrical signals from transient environmental signals), specialists in cardiac transport were able to definitively demonstrate HEMS safety for paced patients [26].

When questions about the electrical environment were settled, focus turned to the movements and vibrations attendant to helicopter transport. In an era in which thrombolytic therapy was the primary treatment for STEMI, there were understandable concerns that high-frequency constant vibrations (such as from jet engines) could mediate increased risk of post-lysis bleeding. Fortunately, these risks turned out not to be encountered or manifest in increase in complication rates. Seminal work by Fromm *et al.* [27] in Texas (US), whose HEMS unit provided large numbers of post-lysis STEMI transports, demonstrated there was no increased bleeding or other risks in the post-lysis population.

With patient safety being demonstrated, HEMS clinical researchers' next task was to ascertain what outcomes benefits may be accrued with use of cardiac air transport. The benefits focused upon were primarily related to STEMI and time savings; these are covered next.

3.2. Moving STEMI Patients to the Cath Lab

In terms of cardiac patient transports and time savings, there is increasing emphasis on getting patients with myocardial infarction to primary PCI as the treatment of choice *if* a 90-minute first-door-to-balloon time can be met; expedited prehospital care—including HEMS—will play an important role in cardiac care systems [28,29]. One of the major dichotomous benefits of HEMS is therefore simply getting patients to primary PCI within the window of benefit.

Unlike the case for some diagnoses, for which crew expertise is a major (and perhaps the most important) factor mediating HEMS' outcome improvement, for PCI transports the key appears to be time savings [16]. Well over a decade ago, cardiologists were positing that the time savings and associated earlier intervention was resulting in myocardial salvage and improved HEMS-related morbidity outcomes such as a 2-day decrease in hospital length-of-stay [15].

In fact, early HEMS studies helped establish the overall desirability of primary PCI as an alternative to thrombolytic therapy. A major study (*Air PAMI*) randomized patients to community hospital lysis or transport (by either ground or air) for primary PCI. Air PAMI results were fascinating: the transported patients took much longer to get to definitive therapy (155 *vs.* 51 minutes) but had a 6-fold improvement in outcome as compared to those who were lysed. The study results were sufficiently compelling even on interim analysis, that the investigation was halted before full enrollment targets were reached [30].

Ongoing study next demonstrated that despite the importance of meeting the dichotomous endpoint of "arrived at the cath lab in time for PCI," there were still benefits to be gained by time savings even within the PCI window. Time really is myocardium. Experts have written that the maximal benefit of primary PCI is accrued in the initial 60 minutes [31]. It is also 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 [17]. Data from 2009 suggest that the inflection points of the time savings and mortality benefit curve, are somewhere around 45 and 225 minutes; this means that time savings is associated with mortality benefit when patients get to PCI within 45 to 225 minutes of initial "door" time [32]. Considered from another perspective, each 30 minutes' additional ischemia time increases mortality by 8% - 10% [33]. Time savings on this level are distinctly possible with appropriate use of HEMS [16].

3.3. HEMS as Part of Cardiac Care Systems

Improvements in times for individual patients inevitably lead to consideration as to how HEMS can be best integrated into systems of cardiac care. Work from both the US and Europe demonstrated the overarching capabilities of HEMS as a tool for extending the reach of STEMI care networks for rapid provision of PCI [22]. There is growing system-based recognition of importance of transporting STEMI patients for PCI. A consortium panel of US EMS medical directors has identified as an evidence-based benchmark for quality prehospital care, the transport of STEMI patients to primary PCI within 90 minutes of EKG diagnosis [34]. Recent meta-analysis confirms the substantial outcomes benefits, in terms of both systems-level mortality and morbidity, of timely transfer of STEMI patients for mechanical reperfusion [35]. For some regions and patients, HEMS provides a vital capability to meet this benchmark.

Just as focus on the entire process from symptom onset to opening of infarct-related artery is important for planners of acute cardiac care, focus on pre-HEMS and post-HEMS activities is necessary to maximize transport-related time savings benefits. In one of the most successful demonstrations of HEMS incorporation into a regional cardiac care system, Blankenship *et al.* [36] used a "before-and-after" approach to examine endpoints of time savings and health outcomes associated with institution of a new triage and HEMS transfer system. The system's goal was to expedite community hospital evaluation and referral of STEMI patients to a PCI center. Protocol changes effected midway through the study included: 1) community hospital STEMI care changes emphasizing time savings (e.g. elimination of heparin and nitroglycerin infusions), 2) simultaneous PCI lab and HEMS activation from a single call to the receiving center, and 3) bypass of the receiving center's Emergency Department (ED) after HEMS transport.

In the Blankenship study [36] from Pennsylvania, for the main endpoint (community hospital presentation to wire-crossing time), the "after" period was associated with significantly shorter times (105 vs. 205 minutes, p = 0.0001). Time savings were achieved by faster HEMS dispatch (from 35 to 16 minutes) and streamlining time intervals between HEMS dispatch and PCI center arrival (from 56 to 45 minutes). The proportion of patients with door to wire-crossing times under 90 minutes increased from 0% to 24%, and the percentage with door to wire-crossing times under 120 minutes also increased (from 2% to 67%). The study successfully made the point that with use of time as a surrogate endpoint, and one that was well-founded on current physiologic understanding, HEMS could be an important component of a system of care. The promising system-based results of the Blankenship group were replicated in a 2013 study that found that combination of HEMS with other streamlined referral processes resulted in a trebling of likelihood of patients getting door-to-balloon time within the desired 90-minute window [37].

The Pennsylvania results have been reproduced elsewhere. A study from Ohio (US), found that patients were nearly 3x more likely to have door-to-balloon times under the 90-minute target when they were transported using a streamlined referral process (that included HEMS "autolaunch") [37]. 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 [9]. A preliminary report on simultaneous HEMS dispatch and tertiary care hospital cardiac cath lab activation by ground EMS providers making STEMI diagnosis during transport to a referring (non-PCI) hospital, found the referring hospital time was reduced from 79 to 31 minutes [20]. Others have also demonstrated the significant time savings able to be accrued from prehospital activation of HEMS for transport directly to the cath lab [38]. For systems-based use of HEMS, the entire system from prehospital through cath lab needs to be considered, and the role of helicopter transport carefully considered for potential integration as part of the overall care network.

3.4. Cost-Effectiveness

Recently, a group from the large rural US state of Oklahoma has generated preliminary data intended for ultimate use in cost-effectiveness calculations. In this paper, the authors were the first to specifically tie time savings to estimated HEMS-mediated mortality improvement [16]. Time savings accrued with HEMS as compared to ground transport were calculated estimated using what is becoming a standard geographical information software (GIS) approach [21]. The authors found substantial time savings. Since the novel study methodology was imperfect, the limited overall conclusions were that the data should serve as the basis for a larger analysis (now ongoing) to assess whether the number-needed-to-treat (NNT) of 59 is consistently estimated in different areas.

If the results of the initial study are replicated in the larger analysis, the NNT of 59 has utility as a variable in the cost-effectiveness analyses important for HEMS and policy-makers.

Systems planners designing cardiac care networks are well-advised to incorporate air (as well as ground) transport into planning. The importance of judicious planning has been demonstrated by work from Ohio (US). McMullan *et al.* [39] found that use of HEMS transport for cardiac patients is no guarantee of arrival to cath labs within recommended time frames. HEMS is potentially important as a *part* of a cardiac care system, but the air medical resource must be used wisely.

A 2010 study revealed that centralization of cardiac catheterization resources, with appropriate build-up of EMS transfer systems, is significantly more cost-effective than construction of multiple cardiac catheterization centers; the authors note that 20% of Americans live more than an hour away (by ground) from a cardiac catheterization center [40]. Complementary information is provided by a report by Peterson *et al.* [41] 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. All of these data contribute to a conclusion that air medical transport does have a role in optimizing cardiac care regionalization.

3.5. HEMS for Other Cardiac Cases

The time advantage is also accrued for patients other than those being transported for primary PCI. For patients failing PCI at referring hospitals, HEMS has demonstrated utility as a backup system for rapid transfer for urgent surgical revascularization [42]. Work from the TRANSFER-AMI group suggests that expedited transfer for mechanical intervention after community hospital lysis is associated with a 50% reduction in a 30-day composite endpoint (death, reinfarction, recurrent ischemia/reinfarction, CHF, or shock) [43].

Another category of "cardiac" patients that has received attention in the HEMS literature comprises those who have had cardiac arrest. In this broad category, initial work proved true, the common-sense notion that HEMS was not indicated for patients in persistent non-traumatic cardiac arrest [44]. The authors of that study noted some potential logistics advantages (e.g., improved availability of ALS in rural settings) entailed in rural HEMS utilization, but they make a strong argument against HEMS benefit for patients in arrest at time of HEMS activation. For those patients who are resuscitated from cardiac arrest, though, the outcome is different; work by Werman *et al.* [45] demonstrates that appropriately dispatched HEMS can be beneficial in post-arrest patients.

4. HEMS for Neurological Patients

The mantra "time is brain" evolved more recently than "time is myocardium," but it is no less important. From early information that described benefits of time savings (such as with stroke patients) in terms of hours [46], the state of the evidence now supports time savings on smaller scales [18]. When considering how to streamline care on the level of these smaller scales—15 minutes' increment can make a difference—HEMS becomes an asset to consider.

4.1. Patient Safety

As was the case for cardiac cases, one of the first items to address was safety. For stroke patients in whom post-thrombolysis hemorrhagic conversion is a major concern, there were safety questions about helicopters and movement (including vibration). Two 1999 studies by Chalela [47] and Conroy [48] established that even in post-lysis patients, there were no increases in rates of stroke complications such as bleeds. In demonstrating the safety of HEMS use for even the sickest stroke patients, Conroy further posited that the relatively minimal "packaging" required for neuro patients translated into ideal setup for HEMS to save time [48].

4.2. Time Savings

It has for over a decade been postulated (with support from pooled analysis data) that there is stepwise outcomes improvement associated with each 90-minute improvement in stroke lysis time (to 270 minutes) [49]. As previously noted, the time frame for which incremental improvement is achieved with more streamlined therapy has continually narrowed. In 2013, Saver *et al.* [18] drew a direct line between improved functional and vital outcome and incremental time savings of as little as 15 minutes. Given clear data from other facets of the HEMS literature that air medical transport very often results in time savings of this magnitude [16,50], it seems quite likely that stroke care networks will continue to benefit from appropriate use of HEMS.

Time savings due to HEMS is relatively easy to characterize for stroke patients, but streamlining pre-neurologic center times can potentially aid a breadth of patients. There are few data describing HEMS crews' savings of time for other neurological conditions, but it is nevertheless the case that (at least occasionally) such time savings are likely to occur and are a critical contributor to improved outcome.

4.3. HEMS as Part of Stroke Systems

Stroke patients were among those emerging time-critical populations for whom regionalization of care translated into advanced therapies' being available primarily at regional centers, and even in the late 1990s air medical transport seemed well-positioned to be a part of stroke systems.

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 [51]. The American Stroke Association Task Force on Development of Stroke Systems [52] identified HEMS as an important part of stroke systems. The report states "Air transport should be considered to shorten the time to treatment, if appropriate."

Authors writing about the utility of HEMS in stroke care systems generally refer to the ability of HEMS to "extend the reach" of tertiary care centers providing time-critical care [19]. The emphasis on time is not unlike the situation with STEMIs: highly trained crew with critical care experience is of course important, but the main contribution of air transport is expedited movement of patients to time-windowed therapy.

The case for HEMS use to optimize stroke lysis rates has been convincingly made in a national registry-based study from Austria. Reiner-Deitmeyer *et al.* [53] used "administration of thrombolytic therapy" as their endpoint, focusing on the capability of air transport to get patients to lysis-capable centers. The authors found that both scene and interfacility HEMS transport allowed for higher thrombolysis rates, and that scene HEMS response was associated with the highest chances of stroke patients' receiving thrombolytics within 90 minutes of symptom onset.

The Austrian study's findings regarding scene transports for stroke confirmed earlier findings from a rural US region (north Florida and southern Georgia). Over a decade ago, Silliman *et al.* [54] explored 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. In short, HEMS was not overused, stroke was not overdiagnosed by prehospital personnel, and many patients were lysed, who would otherwise have not had a chance to receive time-windowed therapy.

The lessons on "scene" calls for stroke have been demonstrated by others as well. For example, the French have reported HEMS response to cruise ships at sea, enabling time-critical and successful lytic therapy for stroke [55].

The authors from the Florida study and also those from Austria join others in demonstrating that a strictly applied stroke triage protocol (roughly based on the trauma triage model) can widen a stroke center's coverage area. Even in highly developed urban systems, there is some role for judicious employment of air medical resources to operationalize the regional adherence to the adage "time is brain [8,56]." _ENREF_38.

From the systems perspective, HEMS is an important part of stroke care networks in which outcomes are improved with stroke care in specialized centers [57]. Addition of air medical resources into logistics calculations halves the numbers of Americans who lack timely (within one hour) access to a primary stroke center (from 136 million to 63 million) [58].

4.4. Cost-Effectiveness

The fact that there is advantage in administering stroke thrombolytic therapy in a more timely fashion is only true to a certain time point. Even for stroke lysis protocols that allow for "late" thrombolysis (up to 4.5 hours post-symptom onset) there remains a "wall" that is not safely crossed. If the patient doesn't get to a lysis-capable center within a certain time frame, the opportunity at morbidity- and mortality-improving lysis care is lost. This strict time-windowing of stroke therapy has generated an important endpoint for HEMS use in stroke care. If HEMS can get patients to stroke lysis-capable centers within a certain time frame, thus allowing them to receiving this salutary therapy, then that is an important benefit of air transport.

However, as is the case with any resource, judgment must be exercised. For cases in which time-windowed therapy has already been administered, the costs and benefits calculations for HEMS employment are quite different as compared to, for example, movement of lysis-eligible patients [59].

Just as employment of HEMS for stroke patients who've already received time-windowed therapy may be questionable, there are data suggesting room for improvement in HEMS triage of non-stroke neurological patients. In a study from Boston (US), authors examined a variety of neurology/neurosurgery patients (largely non-trauma) and concluded there were many cases of HEMS use for neurological conditions that did not in fact warrant air transport [60].

While data are being developed to address questions in more detail, there is cost-effectiveness evidence that strongly supports appropriate use of HEMS for stroke care. Silbergleit *et al.* [61] have clearly shown that air medical transport is quite cost-effective when it enables stroke patients to receive thrombolytic therapy at receiving centers.

4.5. HEMS for Other Neurological Diagnoses

A previously cited study from Boston included mention of various diagnostic categories (e.g. tumor with mass effect) for which HEMS transport was potentially useful [60]. There are few data in the HEMS literature that systematically address air medical transport use for non-trauma neurological conditions other than stroke.

For stroke and other neurological conditions, it has been suggested that the time-critical nature of these diseases lends itself to early intervention by HEMS crews. Neurologists considering how to get their patients leading-edge therapy have theorized about potential benefits of saving an hour or more by having specially trained HEMS crews intervene upon arrival at referring hospital [62].

5. HEMS for Non-Trauma Surgical Patients

It is somewhat ironic, given the trauma surgery roots of air medical transport in general, that there is relatively sparse literature addressing HEMS for non-trauma surgical patients. Most likely this is not because of lack of occasional HEMS utility in these patients, but rather due to the heterogeneity of (and difficulty to study HEMS use in) non-trauma surgical patients.

5.1. Flight Crews and Stabilization of Patients

What HEMS can bring to the table—in part due to experience with trauma—is the rapid stabilization of surgical patients and the direct transport of those patients to the operating room (OR), bypassing the receiving center ED [5]. Whether the patient has perforated viscus or splenic rupture from infection, there are theoretical (yet hard to demonstrate) benefits from expedited air transport. For the most part, these applications of HEMS must be considered on a case-by-case basis.

Other components of HEMS care that are doubtless helpful to some general surgical patients are mentioned in the final section of this review. These "supportive care" benefits from expert flight crews are as applicable in critically ill surgical patients, as they are in other diagnoses.

5.2. Air Transport of Aortic Aneurysm

There is one group of surgical patients that has time-criticality, benefits from direct-to-OR transport, and appears well-situated to gain from rapid HEMS transport: patients with leaking AAA. Perhaps because this patient population is so similar to the trauma population with whom HEMS crews have familiarity, there have been reports of HEMS use to improve outcome in AAA patients.

In fact, one of the earliest mentions of the concept of "direct-to-OR" transports came in 1989, when Kent *et al.* [5]described their rural state (Alabama, US) experience with HEMS' transferring patients directly into the OR. Subsequent assessment of patients in an urban setting (Boston, US) by Shewakramani *et al.* [63] confirmed the utility of air transport for these most unstable patients. They made the case that while overall numbers and difficulty with control groups serves as a barrier to concrete statistical comparison between air versus ground transport, it seems highly likely that expedited movement of leaking-AAA patients into the OR is usually desirable.

6. HEMS for Non-Trauma Pediatrics

Asis the case for many other categories of non-trauma, the group constituting "pediatrics" is characterized by breadth that precludes straightforward outcomes studies. What are present in the pediatric literature, are data describing one major subgroup (neonates) and one major procedural intervention (airway management). These are considered in this section. Although the specific-diagnosis information for pediatric patients is lacking, the fact remains that regionalization of care is quite common in pediatric systems and so it is particularly likely that HEMS (including specialized teams) will have a role in pediatric care systems.

6.1. HEMS and Neonatal Systems of Care

Two decades ago, Pieper *et al.* [64] 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. The study was one of the earliest to establish that air medical transport can be an important part of neonatal care systems. Subsequent studies provided an increasing body of evidence supporting a contention that even patients of high acuity and tenuous stability, such as ventilated neonates, suffer no adverse effect from air as compared to ground transport modality [65].

The literature includes population-based analyses such as that of Berge *et al.* [24] from Norway; the Scandinavians described a 14-year series of 256 neonatal transports. They found that the mortality of those transported from long distances was no worse than those who came by ground from nearby the receiving centers. Just as Straumann's Swiss group [22] had concluded that HEMS allowed far-away patients to benefit from timely access to specialized care and have outcomes just as good as "close-in" patients, Berge's study made the case that HEMS was an "equalizer" of outcomes for neonates who were located distant from receiving centers.

The Norwegian results included findings of HEMS crews' occasional performance of life-saving interventions in transported neonates [24]. The authors also found that, as compared to the pre-transport time frame at referring hospitals, air medical transport crews were actually able to effect improvements in oxygenation, ventilation, and circulation during the transport phase. These results dovetailed with data from Miami reported by Hon *et al.* [65], who assessed air transport versus ground transport (by the same university-based transport team) and found that helicopter flight was not associated with any worsening in physiology in critical intubated neonates.

6.2. Flight Crew Airway Management

For pediatric non-trauma, there are few data on HEMS transport of non-neonatal patients. There is, however, one other source of information relevant to consideration of air medical transport of pediatrics: the airway management literature. Even as pediatric endotracheal intubation (ETI) is being increasingly revealed as difficult and frequently unsuccessful in the ground EMS setting [66], HEMS crews are reporting favorable results. Air medical transport crews are intervening to provide highly successful pediatric ETI, often with rates rivaling those of the in-hospital setting [67,68]. Furthermore, air medical transport crews are able to intervene after ETI and provide important adjustments in cuff pressures, insertion depths, and tube size [69,70].

7. HEMS for Obstetrics

The most cases, the optimal neonatal transport system is the maternal intrauterine environment. With the principle that safe and effective obstetrics transports improve both material and fetal outcome, HEMS use for pregnant patients has been long described. Initial reports outlined the safety (in terms of being able to predict which patients would not deliver while in-flight [71], and subsequent data outlined time and systems benefits to air medical obstetrics transports.

7.1. Obstetrics Systems of Care

Traditional "extending the reach of the system" advantages as previously mentioned for other diagnostic groups, are also applicable to obstetrics patients—HEMS increases coverage area for centralized maternal-fetal hospitals. Particularly in areas characterized by a paucity of maternal-fetal medical specialists, HEMS has been noted to be a vital contributor to system-wide success in optimizing outcomes [72]. In addition to the advantage of simply providing access to centralized care, obstetrics HEMS transports also bring another salient endpoint to the discussion: minimized out-of-hospital time.

7.2. Minimized Out-of-Hospital Time

Minimization of out-of-hospital time applies to HEMS use for obstetrics as much as for any transport population. Over three decades ago, Elliott *et al.* [23] extoled the virtues of air medical obstetrics transport not because of crew capabilities, but rather because of the reduction in intratransport (out-of-hospital) time as compared to ground ambulance use. Elliott's Los Angeles group emphasized that achievement of the major goal of having high-risk patients deliver at receiving centers (thus using the mother as the "best transport incubator") was often only enabled by use of fast-moving helicopters. Aircraft speed allowed obstetricians to be sufficiently comfortable with the low risk of intratransport delivery (undesirable, regardless of transport vehicle) that laboring patients could be moved to centers with needed expertise in maternal-fetal medicine. The advantage reported by the California group was not simply theoretical: referring facility obstetricians reported that in the absence of HEMS availability, a quarter of the cases in their series who were transported by HEMS would have been delivered at referring hospitals.

In keeping with the sense that maternal and fetal outcomes are both optimized by having deliveries occur at specialized centers (rather than rural referring hospitals), van Hook *et al.* [71] reported their rural Texas experience as being similar to that from the Californians. Whereas the Los Angeles-area group noted traffic congestion was the primary basis for concerns about long transport times, in Texas the problem was more one of geography. Over long distances, helicopter transport allowed for safe and effective setup of obstetrics regional centers to which patients were transported for delivery. van Hook's group concluded that their case series supported the view "held by most", that "maternal/fetal risks associated with HEMS transport are at most, minimal [71]."

As previously mentioned, one of the most important HEMS benefits for obstetrics is reduction of the chances of intratransport delivery. This minimization of "out-of-hospital" time is at least as important as any actual time benefits of getting patients to tertiary maternal/fetal medical centers of excellence. A Japanese group has published their experience that underlies the priority of minimizing out-of-hospital time. Ohara *et al.* [72] 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. In assessing a series of 26 HEMS transfers of pregnant women to their institution, Ohara's group found 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). Certainly, to those who provide care for high-risk obstetrics patients, decreasing the out-of-hospital time (and thus the time frame of risk for intratransport delivery), savings of 101 minutes is a substantial benefit.

8. Other Non-Trauma HEMS Issues

The preceding diagnostic situations represent those for which there are at least some available data directly addressing HEMS and outcomes benefit. There are many other situations that are encountered, for which air medical transport's crew capabilities and/or logistics advantages may be of benefit to patients or prehospital care systems. The list of potential types of individual cases for which air medical transport could possibly be useful is too far too lengthy to enumerate in this review. Instead, this final section of the review will address some HEMS benefits that have potential outcomes utility for myriad non-trauma patient types.

8.1. Time Savings

There are some areas in which there is growing understanding of time-criticality of disease management. One example of such, is the population of patients with sepsis. with the advent of studies demonstrating improved outcome from early goal-directed therapy. Recent reviews of sepsis care emphasize the importance of the six-hour goal for institution of high-level sepsis care [73]. While this time frame seems lengthy for air transport in some urban areas, it is quite conceivable that HEMS crews' capabilities could help bring therapeutic approaches and experience to isolated-region patients who would otherwise miss the 6-hour window.

On the logistics front, those considering potential benefits of HEMS should not always assume that air transport doesn't save time if ground transport is "known to be available" at referring hospitals. The authors of a logistics study from the University of Wisconsin [50] assessed transport times from their 20-hospital network and found the *average* HEMS total transport time over the study period was at least as good as the *best* ground transport time. This finding was despite 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. For close-by hospitals, patients accrued an average of 10 minutes' time savings. From further-away hospitals, benefits were more marked: HEMS transport times were up to 45 minutes shorter than achievable by ground transport.

8.2. Critical Medicine Delivery

Perhaps the easiest cases to consider first, are those in which there is clear logistics and speed capability provided by HEMS that is simply not available by surface transport. Examples from the literature include such situations as use of an aircraft to get a young adult lifesaving prostacyclin for adult respiratory distress syndrome (ARDS) [74]. In a similar case, a Canadian group described use of air transport to get critically needed antidotes (fomepizole in one patient, digoxin antibodies 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 [75].

Certainly, case reports do not constitute sole or sufficient basis to justify HEMS existence. On the other hand, these "sporadic" case reports probably reflect a low—but nonzero—frequency with which air assets' logistical advantages mediate significant outcomes improvement. Just as is the case with trauma, for non-trauma cases there will occasionally be times when physicians making transport decisions should remember the time and related benefits accrued only with HEMS.

8.3. Airway and Ventilatory Management

There are data from the broader HEMS literature (including from trauma cases) that can inform judgments about potential benefit from crew expertise. Perhaps the most obvious of these areas of crew contribution are in the airway and ventilatory management arena.

The high ETI success rates of HEMS crews have been addressed elsewhere in this review and in the broader literature [76]. _ENREF_59 The ability to manage airways with high success rates can accrue advantages to a variety of non-trauma cases.

Airway expertise from HEMS crews is not limited to performance of ETI itself. HEMS benefits to patients are seen even after ETI. This is probably due to ventilator management, avoidance of hyperventilation, and better recognition and management of hypoxemia [77,78]. It is illustrative that HEMS has been shown to improve outcome for head-injured patients even when HEMS arrives after ETI has been performed. While focused on head injury, the work of Davis *et al.* [79] from San Diego is telling: even when ETI is performed by ground EMS, HEMS transport improves outcome as compared with ground transport because of post-ETI ventilation practices.

Close attention to parameters such as end-tidal CO_2, as well as intensive training and frequent experience with ventilator management, are likely responsible for the more stable peri-ETI physiology seen with HEMS as compared to ground transport [79-82]. While difficult to measure on a broad basis, it is quite likely that such attention to oxygenation and ventilation is helpful in a variety of non-trauma conditions.

8.4. Critical Care Expertise

In addition to airway management expertise, HEMS crews bring to bear critical care experience that can (like ventilator management) be difficult to statistically summarize but which is nonetheless occasionally important.

For some patients, there is simply no substitute for the technical capabilities and critical care expertise brought to bear by many air medical crews [83].

A 2009 study from France demonstrates some of the mechanisms for HEMS' improvement in outcome. Berlot *et al.* [84] found—in trauma patients, but with likely extrapolation to non-trauma—that as compared to ground EMS, HEMS transport was associated with improved outcomes due to better hemodynamic management.

After being neglected for too long as a priority for acute-care (and prehospital) medicine, the subject of pain care is receiving its due. Experts in prehospital care have written that pain care is a valid endpoint in and of itself [85,86]. Whether due to protocol restrictions on ground EMS or other factors, HEMS providers tend to be far more diligent than ground ambulance providers in assessing and treating pain [86-88]. As is the case for airway and ventilator management, this component of care has potential benefit for a breadth of non-trauma patient types.

9. Conclusion

In summary, HEMS have the potential to bring both crew expertise and streamlined times to non-trauma patients. The importance of considering logistics benefits is underlined by even brief consideration of the enormous breadth of non-trauma situations in which savings of time can contribute to optimal outcome. As outlined in the NAEMSP guidelines for HEMS use [3], these indications include dozens of situations ranging from tumor-mediated cord compression needing radiation therapy, to the need for emergency delivery of an eclamptic, and to the need for emergency valvuloplasty. The spectrum of individual non-trauma patient types that could *potentially* benefit from HEMS is daunting in its breadth, but the task of considering benefits of HEMS in these cases is worthy of attention for both clinicians and researchers. It is hoped that the information in this review can inform and assist those efforts.

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