Controversies in Prehospital Care

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Abstract

Nowhere in emergency medicine are mythology, legend, and tradition as conspicuous as they are in the field of prehospital care (EMS). Images of speeding ambulances with lights and sirens, aeromedical helicopters in flight, and heroic medical interventions in austere environments are awe-inspiring, thrilling, and reassuring to many of us. As dispassionate scientific scrutiny is applied to these and other practices in EMS, however, it becomes evident that many of the current practices and protocols in EMS are not based on any level of scientific evidence. This article will review current evidence about the costs and benefits of some of the most common current practices in EMS. These include the use of lights and sirens and helicopters, endotracheal intubation and its alternatives in airway management, cardiopulmonary resuscitation, advanced cardiac life support, public access defibrillation, and analgesics. It is hoped that by shining the light of scientific scrutiny upon these practices, dogma will be replaced by clinical evidence. Only in this way may cost-effective emergency care be provided for the greatest benefit to the largest number of citizens.

"It is possible to document exactly how much scientific support there is for the efficacy of our present scope of EMS practice, and it is impressively deficient."[1]

Introduction

Nowhere in emergency medicine are mythology, legend, and tradition as conspicuous as they are in the field of prehospital care (EMS). Images of speeding ambulances with lights and sirens, aeromedical helicopters in flight, and heroic medical interventions in austere environments are awe-inspiring, thrilling, and reassuring to many of us. As dispassionate scientific scrutiny is applied to these and other practices in EMS, however, it becomes evident that many of the current practices and protocols in EMS are not based on any level of scientific evidence. This article will review current evidence about the costs and benefits of some of the most common current practices in EMS. These include the use of lights and sirens and helicopters, endotracheal intubation and its alternatives in airway management, cardiopulmonary resuscitation, advanced cardiac life support, public access defibrillation, and analgesics.

It is noteworthy that, of 5,842 publications on prehospital care, only 54 were randomized controlled trials (RCTs). Of these 54 RCTs, four (7%) reported harm from the new therapy, and 74% reported no effect at all. Only seven studies (13%) of the RCTs showing a positive outcome of an intervention were not contradicted, and only one of these examined a major outcome such as survival, and only one of these was placebo-controlled.[1] Thus, there is a dearth of sound scientific support for EMS interventions, and a serious reexamination of EMS practices is needed.

It is hoped that by shining the light of scientific scrutiny upon these practices, dogma will be replaced by clinical evidence. Only in this way may cost-effective emergency care be provided for the greatest benefit to the largest number of citizens.

The Use of Helicopters in EMS (HEMS)

Medical helicopters in EMS were introduced into civilian use in the United States in 1972, and since that time there has been an exponential proliferation in their use.[2] In 2004, there were approximately 700 HEMS helicopters in the U.S., and they transported more than 300,000 patients. Last year, an estimated 400,000 people flew on EMS helicopters and the national fleet, mostly in for-profit operation, is now over 900. Thirty percent of HEMS flights are scene calls, and 70% are interfacility transports.[3] Much of the impetus for the initiation and growth of HEMS was based on the concept of a "golden hour" after trauma, popularized by Dr. R. Adams Cowley. Further, experience with combat casualties in the Korean and Vietnam wars supported the efficacy of rapid transport of wounded soldiers by helicopter. It should be noted that the very existence of such a golden hour has become the subject of debate.[4] The literature on HEMS in civilian use has been mixed though, with some critics referring to these aircraft as little more than "flying billboards."[2]

In one study comparing 337 patients transported by HEMS with 446 matched patients transported by ground ambulance, survival rates were the same. The authors concluded that there was no evidence that HEMS improved survival.[4] In another study, of 947 consecutive trauma patients transported by HEMS to Santa Clara Valley Medical Center in California between 1990 and

2000, 45% were felt to have arrived as slowly or slower than by ground EMS, and 35% of the HEMS patients were discharged directly from the ED. The authors concluded that <1% of the patients in this series had actually benefited from HEMS, and that 0.5% of the patients may have been harmed by HEMS.[5] In a Boston study of more than 1,500 trauma patients transported by HEMS from the scene, 24% were considered to have been inappropriate.[6] A metanalysis of 22 papers with a cohort of more than 37,000 trauma patients transported by HEMS found that approximately 60% were felt to have had minor injuries, and 24% were discharged within 24 hours.[7] Another study of 3,048 trauma patients transported by HEMS found that these patients had longer transport times, with no difference in mortality.[8] A 2001 study found no difference in quality of life 15 months after trauma for patients transported by HEMS compared to patients transported by ground ambulance.[9] In Houston, 122 consecutive, non-cranial penetrating trauma patients were transported by HEMS. The authors concluded that HEMS did not hasten arrival at the hospital and that scene flights for penetrating trauma in Houston were not efficacious.[10] In a 2003 review by Thomas et al. HEMS transport seemed to benefit certain patients in particular systems, while not in others.[11] One US multi-center study of blunt trauma patients found significant mortality reduction from HEMS.[11] Another study from southern Texas, which compared survival rates before and after the cessation of HEMS programs, reached the opposite conclusion.[12] A five-year study of blunt-trauma patients in an urban setting with a sophisticated prehospital care system transported either by HEMs or ground ambulance found no survival advantage for patients transported by HEMS.[13]

Similar conclusions have been reached about HEMS by investigators in Great Britain, Australia, Norway, Italy, and Hong Kong, where HEMS is felt also to benefit a small fraction of those transported.[14-17]

The use of HEMS for children has also been evaluated. A Los Angeles study of 189 pediatric trauma patients transported by HEMS found that 57 (33%) were discharged from the ED.[19] These authors concluded that HEMS for pediatric patients was associated with a high rate of over-triage, with no additional prehosptial interventions, when compared with ground transport. A Washington, D.C., study of nearly 4,000 pediatric trauma patients transported by HEMS found that nearly 85% were over-triaged and did not require HEMS.[19] Another study from New Jersey evaluated the utilization of HEMS for pediatric trauma patients. The authors found that pediatric patients transported by HEMS were equally severely injured as were those transported by ground, in contrast to adult patients, for whom the HEMS was reserved for the most severely injured patients. They speculated that, because trauma triage schemes were designed primarily for adults, ground personnel are more selective about which adult patients are flown to a trauma center and less selective for children. They recommended the development of pediatric trauma triage protocols.[20]

It has been estimated that approximately 28% of the US population has access to Level I or Level II trauma center care within an hour only by helicopter. The discontinuation of HEMS was found to have a detrimental impact on mortality in one system in interfacility transport to a tertiary trauma center.[21]
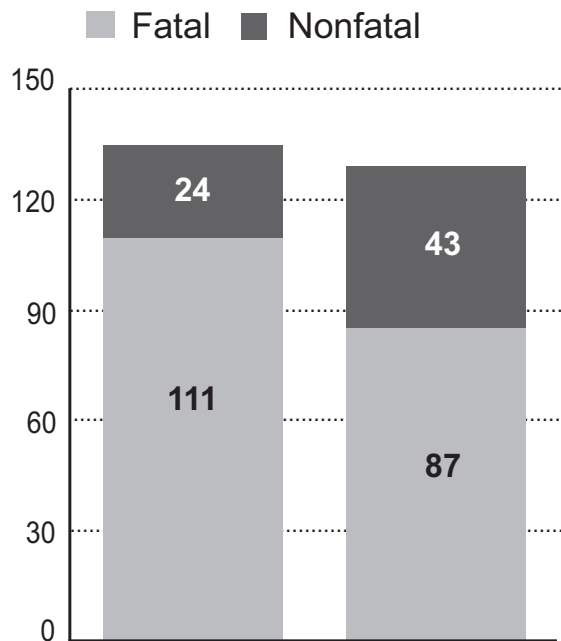
Noise levels in most helicopters while in flight prevent accurate physical examination and auscultation and are a limiting factor for managing patients. Airway interventions are often difficult or impossible in flight, and, if the patient deteriorates en route, management may be extremely difficult.

Medical helicopters are estimated to cost between $1,500,000 and $5,700,000, depending on their configuration and equipment.[2,23] The annual cost for operating a helicopter is estimated to be approximately $1 million.[13] It is estimated that each helicopter requires five hours of maintenance for each hour it flies.[22] The HEMS system at the University of Michigan had operational costs of $6 million, but generated $62 million in inpatient revenues and 28% of ICU days. HEMS patients were also twice as likely to have commercial insurance as were other patients.[2] Some authors have speculated that the proliferation of HEMS is a direct result of successful negotiation for favorable rates of reimbursement. In 2004, the number of flights paid for by Medicare was 58% higher than three years earlier. Spending for HEMS by Medicare more than doubled to $103 million over the same period. In 2002, Medicare increased the rates for HEMS, with prices of from $5,000 to $10,000 per flight, or five to ten times the rate for ground transport. In one study of adult cost per life-year saved, HEMS was calculated to be about $2,500. This compares to $18,000 for neonatal ICU stays for birth weights 500-9999 g; $19,000 median for 310 medical interventions; $23,000 for three-vessel coronary artery bypass for severe angina; $32,678 for thrombolytic therapy for acute MI; and $41,000 for AZT prophylaxis after needle stick.[24] In a 2002 Finish study that dealt with HEMS transport for both trauma and non-trauma diagnoses however, the cost per life-year saved was $30,000.[14]

In addition to the debates about the efficacy and expense of HEMS is the issue of safety. As HEMS usage has increased, so has the number of helicopter crashes. There was a steady and marked increase in the number of HEMS accidents in the United States from 1993 to 2002. Over this period, there were 84 crashes involving 260 people (passengers, patients, crew, and pilots). Of these, there were 72 deaths and 64 injuries. Fifty-two percent of the accidents occurred during the last three years of the study.[25] HEMS aircraft have killed 28 people in seven separate accidents in 2008, which has been the deadliest year for EMS helicopter crashes to date. Since 1987, more than 200 EMS helicopters have crashed, killing 202 people, (Figure 1). This year's fatalities are twice as many as any past year, according to the Comprehensive Medical Aviation Safety Database, a product of Humanitarian Research Services.

In 2001, there were 12 fatalities per million flight hours for all helicopters, but there were 19 per million for HEMS. Between 1995 and 2001, the rate of occupational deaths per 100,000 was five for all workers, 26 for farmers, 27 for miners, but 74 for HEMS crew. At this rate, it is estimated that a HEMS pilot or

Helicopter EMS Accidents Since 1987

SOURCE: Comprehensive Medical Aviation Services' Database, a product of Humanitarian Research Services

Figure 1: Helicopter EMS crashes since 1987

crew flying 20 hours per week for 20 years would have a 40% chance of a fatal crash. Thirty-nine percent of all HEMS crashes result in one or more fatalities. HEMS crashes are associated with post-crash fire and often occur in darkness or bad weather. Darkness more than triples the risk of fatalities, and bad weather increases the risk eight-fold.[26] According to National Highway Transportation (NHTSA) data, causes of HEMS crashes in decreasing order are pilot error, mechanical failure, and undetermined causes.[25] A 2001, HEMS survey found that many pilots felt that they were under unreasonable pressure from management, dispatchers, and flight crews to speed response or lift-off times, to fly when fatigued or ill, and to launch or continue flights in marginal conditions.[27] Medical specialists in sending and receiving hospitals also may feel increased pressure from hospital management to use helicopter services when ground transport would have sufficed.

The Injury Severity Score (ISS), Revised Trauma Score, (RTS) and the Trauma Injury Severity Score

(TRISS) have all been investigated as predictors of the need for HEMS in trauma. It has been observed that patients whose injury severity is in the mid-range of the bell-shaped distribution of trauma severity (i.e., those with ISS between 15 and 45 to 60) are the ones most likely to benefit from HEMS. In studies

from North Carolina and Pennsylvania, those patients with an ISS between 15 and 40 had the clearest benefit of HEMS.[28,29] In a Boston area study of patients with moderate-to-severe trauma, HEMS was felt to confer a 24% mortality reduction in a similar group of patients who were transported by ground EMS. The mechanism of injury alone has been found to be a poor indicator of who benefits from HEMS.[30]

HEMS operational safety could be improved by using stricter weather guidelines, medical-necessity algorithms, and standardized fly/no-fly protocols for pilots. Also suggested are instrument flight rules, night-vision devices, dual pilots, and enhanced minimum pilot qualifications. Regional triage guidelines for HEMS should be established and followed.[14,26,30, 32-4] Data-driven and team-based utilization review of the appropriateness of the transport should also take place. This review must be nearly concurrent with the flight, and it must be applied to all flights. Overtriage, (the use of HEMS to transport patients who are not critically ill or injured) and undertriage (the failure to use HEMS to transport patients who are critical) are two measures used to judge the appropriateness of HEMS. Trauma centers have a built-in accommodation for an overtriage rate of up to 50% in order to have an acceptable undertriage rate (often quoted to be up to 10%).[14,30]

Current medical literature and EMS experts have suggested that HEMS resources might be better allocated by following the Australian and German models of state-run, rather than hospital-owned and based, services. In the US, HEMS operation as part of an EMS or governmental entity (e.g., Maryland State Police) might also improve appropriate usage. As stated above, a HEMS usage criterion, based on physiological parameters rather than on mechanism of injury, has also been recommended. Also, by concentrating on rural responses rather than inter-hospital transfers and urban responses, resources might be better allocated.[2,30]

One HEMS authority, Dr. Thom Mayer of Inova Fairfax Hospital in Virginia, perceptively observes that, "it's not how long it takes the patient to reach the regional critical care center, but rather how long it takes the resources of the regional critical care center to reach the patient. In this respect, the critical care flight crew is an extension of the regional center and may be a key determinant of outcome." He has stated that in his EMS system, HEMS is appropriate if the patient at the scene would have warranted a trauma code if he or she were in his hospital's emergency department (e.g., airway emergency, BP <90 with signs of shock, GCS < 8, traumatic paralysis, penetrating head, neck, or torso injury, major crush or amputation, compartment syndrome, > 20% BSA burn, and extremes of age), unless the patient is less than five minutes from the trauma center by ground ambulance.[30]

It was estimated in one study that, in a mixed rural and urban EMS system, one may convert air and ground miles estimates by using the relationship: lights and sirens ground miles = 1.3 X air miles. The authors suggested the use of this conversion coefficient in designing reasonable helicopter utilization policies.[31]

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The considerable debate on the appropriate use of HEMS will continue, and it will be intensified by spiraling health care costs, increasing medico-legal scrutiny, the recent uptick in crashes, and by health care market forces, among many other competing pressures.[32-35]

Ambulance Light and Siren Use

The use of lights and siren (L&S) during ambulance transport of critically ill and injured patients (a.k.a. "Code 3" transport) is commonly employed by EMS systems. Prominent among reasons cited for using L&S are critical patient status and critical system status, in which there is pressure to return the ambulance rapidly to be available for other calls. It is clear that the indiscriminate use of L&S is a significant contributing factor in ambulance crashes. It has been estimated by a variety of sources that Code 3 status is warranted in only approximately 5% of ambulance runs. Empirical data confirm that the use of L&S far exceeds this estimate.

A 1994 study evaluated the use of a protocol that limited Code 3 transport in Pennsylvania. Before implementation of the protocol, L&S were employed in 58 % of ambulance runs.[36] Use of the protocol reduced Code 3 transport to 8% of ambulance runs. Of the remaining 92% of patients transported without L&S, no patient was judged to have sustained an adverse outcome related to transport mode. A New York study of L&S transport found that their use only reduced response times by an average of 106 seconds.[37] These authors concluded that, "Although statistically significant, this time savings is likely to be clinically relevant in only a few cases." A similar study conducted in Minnesota over a nine-month period found that L&S use decreased response time an average of 3.02 minutes compared to non-L&S use.[38] A North Carolina study compared transport times of EMS with L&S and without, when the trip length was less than eight miles. The authors found that L&S saved an average of 43.5 seconds per trip, and they concluded that, "Although the mean difference is statistically significant, it is not clinically significant, except in rare circumstances."[39]

In a recent Pennsylvania study of 245 consecutive patients who arrived by Code 3 transport, only 14% received an ED intervention within 15 minutes of arrival, and only 54% were ultimately admitted to the hospital.[40] In Cincinnati, L&S were employed in nearly two-thirds of over 500 ambulance runs to a pediatric medical center. The use of L&S was considered to be inappropriate in 39% of the runs, and its use was more common in basic ambulance units than in paramedic units. The authors concluded that L&S transport of pediatric patients in their system was often inappropriate and that protocols should be established to limit L&S use.[41]

A retrospective study of data from the Rapid Early Action for Coronary Treatment (REACT) trial compared the mode of transport of chest pain patients in 20 US cities. Patients transported by private transportation arrived more quickly than those who arrived by ambulance (35 minutes vs. 39 minutes). The authors noted that, although activating 9-1-1 is the most rapid way to

achieve definitive medical care, only 50%-60% of patients with chest pain choose to initiate care via EMS, principally because of their perception that private transportation is quicker. "Door-to-needle" time was faster in the EMS patients, however (32 vs. 49 minutes).[42]

The unrestricted use of L&S is not only medically inappropriate, but it is also dangerous. It has been estimated that 12,000 EMS crashes result in 120 deaths in the United States and Canada annually. Most of these crashes are associated with the use of L&S and involve more frequent and more severe injuries than are sustained in crashes in non-Code 3 transport.[41-44] As a result of these increased injuries, liability claims are more than 20 times more likely to result from EMS vehicle crashes than are claims involving the EMS patient care. In 2004, 170 fatalities in the US occurred as a result of emergency vehicle crashes, according to NHTSA.

During the years 1991-2000, the MMWR reported 300 fatal crashes involving occupied ambulances, with 82 deaths of ambulance occupants and 275 occupants of other vehicles and pedestrians.[44] A total of 816 ambulance occupants were involved in these 300 crashes. Twenty-seven of the occupant fatalities were on-duty EMS workers, representing 3% of all ambulance occupants and 33% of occupant fatalities. Most of the 27 EMS worker fatalities occurred in the front of the vehicles. Riding or driving unrestrained was cited as a major contributor to death and injury. Less than half of the EMS workers in the rear compartments use restraints, often citing unsatisfactory access to the patient for IV insertion, CPR, and airway management. Additionally, unrestrained patients in ambulance crashes have the potential to become airborne and to endanger other rear compartment occupants. Three times as many bystanders (either pedestrians or occupants of other vehicles) were killed as were EMS personnel.[42,44]

EMS workers in the United States have a fatality rate of 12.7 per 100,000 workers, more than twice the national average, and most of these fatalities are due to vehicle crashes. By comparison, the fatality rate for police is 14.2, and it is 16.5 for firefighters.[44, 45]

Also frequently cited in ambulance crash literature is the "wake effect" – the tendency for the racing Code 3 ambulance to precipitate crashes of other vehicles in its wake. A study from Salt Lake City substantiated the existence and magnitude of wake-effect collisions. Sixty ambulance crashes and 255 wake-effect collisions were reported. The study suggested that wake-effect collisions are real and that these probably occur with a greater frequency than do ambulance crashes.[46]

Restriction of the use of L&S to a prearranged set of indications is likely to minimize ambulance personnel injury. The National Association of EMS Physicians (NAEMSP) and other organizations have policies regarding the prudent use of L&S. It is clear that personnel in many EMS and fire systems feel inadequately trained in vehicle operation safety, especially when compared to their counterparts in law enforcement.

It is also evident that EMS personnel knowledge is poor regarding basic traffic safety laws pertaining to emergency vehicle operation.[47] In a sample of 293 EMTs at East Carolina University, the median number of correct responses to five knowledge questions about ambulance operation was one. The median number of correct responses to the five knowledge questions was one (range zero to four). Thirty-three percent of the EMTs knew that other vehicles are required by law to yield while either approaching or being overtaken by an ambulance with warning lights and sirens; 2% knew that due regard for safety is the only requirement of an ambulance approaching a red light at an intersection; 14% knew that the minimum following distance behind an ambulance is one city block; and 28% knew that there is no speed limit on ambulances with warning lights and sirens. Respondents were more likely to score above the median if they had taken one or more emergency driver's education courses or had nine years or more of EMS experience.[48]

In a review from Virginia, while 75% of ambulance runs were conducted with L&S, a disproportionate number (91%) of collisions occurred during L&S operation. The responding ambulance driver had a history of multiple EMS crashes in 71% of the collisions.[49,50]

All operators and front-seat passengers of ambulances must use seat belts. Any patient on a stretcher must be secured while the vehicle is in motion, and all EMS personnel in the patient compartment must use seat belts when not attending to the patient. It is unrealistic to expect the public to use seat belts if healthcare workers fail to use them.

Prehospital Analgesia

In the words of Albert Schweitzer, "We must all die. But that I can save a person from days of torture, that is what I feel is my great and ever-new privilege. Pain is a more terrible lord of mankind than even death itself."

While the goal of medicine is largely to decrease pain and suffering, pain management in EMS continues to be woefully inadequate. This is despite the observation that up to 70% of our patients experience pain as part of their presenting problem.[49] Among the organizations that have position papers on the use of analgesia in EMS are the National Association of EMS Physicians, the American College of Emergency Physicians, the American Academy of Pediatrics, the American Medical Association, the American College of Obstetrics and Gynecology, and the American College of Surgeons.

One study showed that up to 20% of EMS patients have moderate-to-severe pain.[51] Other studies have revealed that medical practitioners in general and EMS workers in particular are poor at recognizing and managing pain. In one EMS study of 1,073 patients with suspected extremity fractures, only 1.8% were administered analgesics and 17% and 25% received ice packs and air splints, respectively.[52] In another study of 124 patients with an emergency department diagnosis of hip or lower extremity fractures, only 18.3% were administrated field analgesics. In Australia, of 128 patients with a prehospital diagnosis of femo-

ral neck fractures, only 51% received analgesics by EMS.[53,54] In addition to the infrequent administration of analgesia by prehospital personnel, the patients who receive their first analgesia after arrival at the emergency department wait much longer to receive them. In one study, this time was 28 minutes vs. 146 minutes on average.[55] In a second study, the time was 23 minutes and 113 minutes respectively.[56] There are several barriers to adequate analgesia in EMS. The first is that many states still require physician contact before the administration of narcotics. Next, few EMS textbooks devote significant attention to analgesia, and EMS education is often inadequate in this field. Also, there are many EMS systems that have no written protocol for analgesic administration. In addition, there is often reluctance by EMS personnel to administer analgesia for fear of conflict with the emergency physician. Lack of education and research and of agent availability are also cited.[57] Prejudices about EMS analgesia administration may include a belief that its use may mask important physical exam findings and that it may lead to addiction. EMS care providers overestimate their abilities to accurately assess a patient's pain by observation alone. There is also an unfounded concern that analgesic administration might make later informed consent impossible. Also cited is a fear of regulatory oversight and misunderstanding about the likelihood of adverse events.[56] Ethnicity of the patient has also been shown to affect pain management. A UCLA study showed that Latino patients with isolated long bone fractures were half as likely to receive pain medication as were their non-Latino white counterparts.[57] A New Orleans study showed the same finding for African-Americans.[58] Children and adolescents have been shown to have less documentation of pain assessment by EMS personnel and to be less likely to receive analgesia.[59,60] Women have been shown to be less likely than men to receive prehospital analgesia for isolated extremity injuries.[61] Decreasing levels of income are also associated with decreased rates of analgesia administration.[56,61,62]

Among the most accurate means of pain assessment by EMS providers is self-reporting by the patient. In addition to this, visual analog scores, numeric pain scales, and pediatric FACES pain scales are useful in measuring pain degree and of its responsiveness to analgesics. Multiple studies have demonstrated that narcotic analgesics actually make subsequent abdominal examinations more accurate. Further, it has never been shown that analgesics given judiciously for legitimate pain interfere with informed consent or that they lead to drug addiction.[63] Several reports have demonstrated the safety of EMS narcotic administration.[64,65] In one such study of 84 cases using small intravenous doses of morphine (2-4 mg), there was only one case of respiratory depression. In another study of 131 HEMS patients there were no complications from intravenous fentanyl administration. Of another cohort of 2,129 patients who received intravenous fentanyl by EMS, 12 patients (0.6%) had a transient vital sign abnormality and none required any intervention.[65] Thirty-seven states allow standing orders for narcotic analgesic administration, and 16 states endorse standing orders for fentanyl for pain management for extremity fractures and burns.

The ideal EMS analgesic has a short onset of action and time to peak effect and a short duration. It causes minimal hypotension, respiratory suppression, and nausea. It is easy to administer, is inexpensive, reversible, and it has multiple routes of administration. Fentanyl citrate (Sublimaze) is one such medication.[65] It has intravenous, intramuscular, intranasal, transmucosal, and transdermal routes, and it may be used in adults and children.[65]

Several other medications have been studied in EMS and have been found to be efficacious: nitrous oxide (Entonox) and methoxyflurane inhalers, morphine sulfate, tramadol (Ultram), butorphenol (Stadol), ketamine (Ketalar), and alfentanyl (Alfenta).[66-76] Non-pharmacological interventions have also been studied and have been found to be effective. Among these are guided imagery, biofeedback, breathing exercises, emotional support, splinting and positioning, elevation, and ice or heat. In one EMS study, patients who received acupressure were found to have less pain, less anxiety, a slower heart rate, and greater satisfaction than did patients in a control group.[77]

Among measures that have improved prehospital pain control is the use of objective pain instruments in the assessment of the presence and degree of pain.[78,79] By the agreement of EMS physicians and field personnel, administrators, and receiving hospital personnel, a comprehensive prehospital pain plan would liberalize protocols and move most real-time pain management decisions from on-line medical control to written protocols. Such a protocol was found to reduce the time to morphine administration by 2.3 minutes in one study of isolated extremity fractures.[80]

In summary, prehospital pain management can be performed safely when appropriate drug choices, protocols, education, documentation, and quality management tools are integrated. Only by emphasis on pain education, research, protocols, and monitoring will the assessment and management of pain in the prehospital setting improve. This is both humane as well as being good medicine.

EMS Airway Management

Among the most hotly debated issues in EMS currently is optimal airway management. With the introduction of paramedics in the 1970s, increasingly sophisticated airway care was available in the field. In a series of reports in the literature from the 1970s and 1980s, it seemed that prehospital endotracheal intubation (ETI) was feasible and effective, and it has largely come to be considered the standard of prehospital airway care. In theory, ETI achieves tight regulation of oxygenation and ventilation, protects against aspiration, allows suctioning, and provides an alternate route for drug administration.

In 2001, Katz and colleagues took a fresh look at ETI in his EMS system.[81] For many, the results were shocking. Fully one-quarter of the endotracheal tubes were misplaced, (i.e., tip of ET tube above the cords in the hypopharynx, or in the esophagus). In another report in 2003 from Maine by Jemmett et al., prehospital endotracheal tubes were misplaced at a rate of 12-15%[82] In a retrospective review of over 4,000 with severely head injured patients in Pennsylvania, 44% of patients were intubated in the prehospital setting, and the rest were intubated after arrival in the emergency department. The adjusted odds ratio for death for the patients receiving prehospital intubation was 3.99. Prehospital intubation was also associated with worse neurological and functional outcomes: 18.2% vs. 15.5%, respectively.[83]

In a study of 8,786 adult trauma patients, prehospital ETI and positive pressure ventilation in severely injured adults (GCS of 8 or lower, and an ISS of 16 or higher) was associated with an increased risk of early hypotension and an increased mortality.[84] In another series of 852 patients with severe head injury (GCS < 8) who were admitted to one of 13 trauma centers from 1995 to 1997, the relative risk of mortality was 1.74 in intubated patients and 1.53 in patients undergoing unsuccessful intubation attempts. A "Best Evidence Topic Report" from the Emergency Medicine Journal examined whether prehospital ETI was superior to bag-valve-mask (BVM) ventilation in 17,676 patients in eight relevant papers.[85] The authors found that patients undergoing ETI had longer prehospital times as well as higher mortality when compared to the BVM group. A 2003 study from the R. Adams Cowley Shock Trauma Center in Baltimore prospectively studied 191 severely head-injured adult patients who survived at least 48 hours after admission. In comparison to the 59% of patients receiving BVM in the field, those 41% who were intubated in the field had a longer mean duration of mechanical ventilation, longer hospital stays, an increased rate of pneumonia, and a higher mortality (23% vs. 12.4%). In a 2005 study, 13,625 moderate-to severely-brain injured patients were studied.[86] Prehospital ETI was performed in approximately one-fifth of the patients. Intubated patients had a mortality rate of 55% compared with 15% in those without prehospital ETI.

Gausche and coworkers at Harbor-UCLA Medical Center in Los Angeles published a three-year study of 830 pediatric patients comparing survival and neurological outcomes of prehospital BVM vs. ETI.[87] More than 2,500 paramedics in Los Angeles and Orange Counties received intensive pediatric airway training prior to the study. The study found no significant difference in survival or in achieving a good neurological outcome among children receiving either procedure. This was the first controlled study comparing the widely used BVM and ETI treatments in either adults or children and is the longest and largest controlled trial of treatments for children in a prehospital setting to date. BVM was found to be as effective as ETI in an urban EMS system. The study also demonstrated increased scene times and overall times when ETI was used. ETI was associated with a significant rate (8%) of fatal complications. Children are especially susceptible to tube dislodgements due to their short tracheal lengths. Therefore, once an endotracheal tube was placed, there was a significant risk of dislodgement, which occurred in 14% of cases. According to Dr. Gausche, "It is clear to me that the best way to manage a child's airway in the field who require ventilatory support is via BVM ventilation."

In the San Diego Rapid Sequence Intubation (RSI) trial, Dunford et al. found that oxygen desaturation (SaO2 <90%) occurred in over half of cases, bradycardia (heart rate < 50 beats per minute) occurred in 19%.[88] Despite this, paramedics described the intubations as "easy" in 84% of the cases in which desaturation occurred. The RSI group had lower rates of "good outcomes," longer scene times, and more frequent inadvertent hyperventilation, when compared to a control group. Fifty percent of the RSI group experienced transient hypoxia. It will be noted that, in traumatic brain injury, the combination of hypoxia and hypocapnea is a recipe for secondary brain injury. The PACE II trial studied 1,953 prehospital intubations in over 40 EMS agencies in Pennsylvania. In these intubations, 22.7% (of 1 in 4.5) patients were exposed to at least one of three errors: 1) tube misplacement or dislodgement, 2) multiple attempts defined as four or more laryngoscopies, and 3) intubation failure. There was significant variability in intubation success rates between agencies, with some experiencing error rates as high as 30-40%.[89]

Another study from San Diego evaluated the relationship between hypoxia and increased mortality in 13,625 patients with moderate to severe traumatic brain injury. The mortality rate was 55% for patients undergoing prehospital ETI compared with 15% for those without invasive airway management. In two other studies, targeted ventilation rates in traumatic brain injury patients were associated with lower mortality when compared to hyper- or hypo-ventilation.[90]

In a 2005 Texas study, prehospital ETI and positive pressure ventilation in severely injured adults was associated with an increase in hypotension upon arrival in the ED (54% vs. 33%) and decreased survival (24% vs. 45%).[90]

An observational prospective study at the Indiana University School of Medicine found that, of 208 consecutively enrolled patients who were intubated in the field (77% medical and 23% trauma), 5% of orotracheal, and 11% of nasotracheal ETIs were misplaced.[91] Stringent paramedic training requirements and close medical direction were cited by the authors as possible reasons for these lower rates of misplaced ETIs when compared with other current studies.

A significant complication of ETI is the aspiration of gastric contents. One new and ingenious method of detecting gastric aspiration after ETI was by described by Ufberg et al. at Temple University.[93] They tested sputum specimens obtained after ETI for the presence of pepsin, a marker of gastric contents. From pepsin, they were able to determine the rate of aspiration in the prehospital setting. Their conclusion was that prehospital ETI was associated with aspiration with an odds ratio of 3.5 when compared with ED intubation. In a second study, Ufberg et al. went on to show that aspiration syndrome was present in more than half of pepsin assay-positive patients vs. 21% of assay-negative patients and that death occurred in patients with aspiration syndrome in 44% vs. 12% in patients without the syndrome. Thus aspiration syndrome after emergent intubation was strongly associated with death during hospitalization.[94]

The gold standard in assuring adequate ventilation in emergency departments and operating rooms is waveform CO_2 capnography.[95] This monitoring technique is not generally available in the prehospital setting, where tube placement is usually confirmed by a combination of other techniques: esophageal detector device, direct laryngoscopic visualization, and colorimetric CO_2 detector.[96,97] In one report, the use of end-tidal CO_2 monitoring decreased the rate of endotracheal tube misplacement from 23.3% to 0%. Eventually, waveform CO_2 capnography is likely to become the standard of care in the field.[98]

Another promising new device in prehospital airway management is the airway impedance device (ITD, Res-Q-Pod, Advanced Circulatory Systems, Inc. Eden Prairie, MN. This device is recommended as a Class IIa device in the 2005 American Heart Association CPR Guidelines, and thus is more highly recommended than any other device or drug used by emergency personnel for increasing circulation during CPR and for improving resuscitation rates.[108] The ITD is introduced between the endotracheal tube and bag-valve and is intended to prevent over-bagging of intubated patients, thus addressing the hazards of increased intrathoracic pressure and impeded venous return. In several reports this device has been found to increase systolic pressures safely and significantly in patients in cardiac arrest compared with sham controls, thus increasing blood flow to the heart and brain during assisted ventilation. It has been shown to be effective with standard CPR and with other methods of CPR (i.e., active compression decompression - ACD).[109] It is hoped that its use will increase the rates of survival and normal neurological function after cardiac arrest.

In addition to the problems created by over-bagging of intubated patients are the problems caused by over-inflation of the endotracheal tube (ETT) cuff. Such over-inflation can lead to severe complications, such as tracheal necrosis, laryngeal nerve palsy, and tracheoesophageal fistulas. Under-inflation can lead to air leaks, inadequate ventilation, and aspiration. In one study, every one of 53 experienced paramedics inflated the ETT cuff over the safe pressure limit of 25 cm H_2O. In 66% of the cases, the ETT cuff pressure was over 120 cm H_2O, and 87% of paramedics could not detect an over-inflated ETT cuff by palpation. The authors recommended use of commercial ETT cuff inflation devices to achieve optimal pressures and the checking of cuff pressure with a manometer.[110]

A potential solution to the problem of prehospital intubation failures and complications is to use alternative airways such as the Combitube, Laryngeal Mask Airway, and the King LT airway (King Systems Corporation). Regardless of the solutions chosen to avoid airway complications in EMS, it is clear that the airway is the paramount consideration in resuscitation and rescue. Misplaced airways are a problem. Undetected misplaced airways are disasters. Any steps that can assure a secure and functional rescue airway in EMS must be adopted immediately.[111-115]

Cardiopulmonary Resuscitation and Advanced Cardiac Life Support

Sudden cardiac death is a major public health problem affecting 400,000 patients annually in the United States, with the majority of these occurring in the out-of-hospital setting.[116] Mortality rates are high and reach almost 100% when prehospital care has failed to restore spontaneous circulation. Overall survival remains at approximately 5% in most communities. Of the survivors, only about two-thirds have good neurological function. Advanced cardiac life support (ACLS) is the "fourth link" in the American Heart Association's "chain of survival": early EMS care, early CPR, early defibrillation, and ACLS. But among the more disturbing recent revelations about the effectiveness of ACLS was a 2004 report by Stiell and colleagues that appeared in the New England Journal of Medicine.[117] The authors, members of the Ontario Prehospital Advanced Life Support (OPALS) trial, evaluated the contribution of paramedic-provided ACLS care to survival. Patients treated in an initial rapid defibrillation cohort were compared to a later group who also had prehospital ACLS care. During the second (ACLS) phase, although there was a significant increase in the rate of return of spontaneous circulation and of survival to hospital admission, there was no increase in survival to discharge. The authors concluded that resources should be concentrated on increasing bystander CPR and early defibrillation rather than on prehospital ACLS (e.g., intubation, medications). For prehospital respiratory (as opposed to cardiac) distress, the OPALS investigators found that there was a decrease in mortality with the introduction of an advanced life support program, even though ACLS interventions were rarely used.[118] Other symptomatic treatments, such as nebulized albuterol and sublingual nitroglycerine, were added to an existing basic life support system simultaneously with the ACLS measures of ETI and intravenous medications. The contribution of the ALS measures to the overall benefit to respiratory distress patients could not be determined in this study, but the ALS group mortality was 14.3% vs. 12.4% in the pre-ALS group.

The effect of advanced life support on survival in children sustaining out-of-hospital cardiac arrest (OOHCA) has also been studied. In a 2002 retrospective chart review from Children's Hospital of Pittsburgh, survival rates of children in cardiac arrest who received basic life support (i.e., BVM ventilation) were compared with those receiving advanced life support (i.e., intubation, defibrillation, epinephrine, bicarbonate, atropine). There were no significant differences between the two groups in survival to hospital discharge.[119]

In both the OPALS and other studies, the most important predictors of survival to discharge of OOHCA were arrest witnessed by a bystander, early CPR, and early defibrillation. Valenzuela and colleagues showed that time to defibrillation was strongly correlated with survival.[120] Survival with defibrillation at nine minutes was 4.6%, eight minutes 5.9%, seven minutes 7.5%, six minutes 9.5%, and five minutes 12.0%. In the OPALS trial, defibrillation before eight minutes correlated with an odds ratio of survival of 3.4.

One fundamental assumption about CPR that may be erroneous is that the addition of ventilation to chest compression is necessary. In a well designed 2007 study that was published in Lancet, Nagao et al. found that CPR done with chest compressions only was just as effective as that performed with ventilation.[120] In this prospective observational study of 4,068 adult survivors of OOHCA, 71% had no bystander CPR, and these patients had a 2% positive neurological outcome. Of the remaining 29% of patients who received bystander CPR, 11% had compression-only resuscitation and 18% had conventional CPR with ventilation and compression. There was a favorable neurological outcome at 30 days of 5% in both of these groups, with no differences in survival. Given the possibility that bystanders in an OOHCA might be reluctant to perform mouth-to-mouth ventilations, this research supports the efficacy of omitting artificial respiration.

Wik and colleagues investigated whether defibrillation should always be attempted first or whether it should be preceded by a period of CPR. They found that when defibrillation was delayed more than five minutes, there was an improvement in ROSC in patients who received chest compression for three minutes prior to defibrillation (58% vs. 38%).[121] In another study, 90 seconds of CPR prior to defibrillation resulted in higher survival if EMS response time exceeded four minutes.[121-123]

Wik et al. also evaluated the quality of CPR during OOHCA in 176 adults in England, Sweden, and Norway, and found that a large proportion of CPR was performed poorly.[121-123] Chest compressions were not performed 48% of the elapsed time that there was no spontaneous circulation, (38% if accounting for time to evaluate the EKG and for defibrillations). Further, the mean compression depth was 34 mm, compared with the recommended depth of 38 to 51 mm. Similar results were obtained in a University of Chicago study, which found that chest compressions were performed too slowly and too shallowly, that ventilation rate was too fast, and that too long a period of no compression took place for CPR to be effective in many cases. Thus, the poor quality of CPR itself may have much to do with the persistently dismal (5-10%) survival rate after CPR that is often quoted.[127]

The relationship of survival and EMS response times has been evaluated. Papers by Pons et al. and Blackwell et al. have questioned the generally-accepted national benchmark of eight minutes that is used in most urban areas.[128,129] It is known from the OPALS data that survival after cardiac arrest declines dramatically after five minutes,[122] yet the National Fire Protection Association has set its target for communities to "provide for the arrival of an ALS company within an eight-minute response time in 90% of incidents." But in practice the response time target is nine minutes, not eight, since the benchmark actually strives for nine minutes zero seconds with 90% reliability. This response time is obviously not likely to improve survival in OOHCA (see discussion of AED deployment below).[130]

It is widely accepted that, for each minute a patient remains in VF and defibrillation is not provided, the chances for survival

drop by almost 10%. Further, after ten minutes, the chances for resuscitation are near zero. Considering the pivotal role of defibrillation in survival of OOHCA, public access defibrillation has been intensively investigated. The PAD trial was a multicenter study sponsored by the National Institutes of Health, in which intensive public education was combined with AED installation in "high risk" settings. These included a total of 1,250 places where there were usually more than 250 people over 50 years of age for most of each day, and places where OOHCA had occurred within the past two years. The primary endpoint was survival to discharge. Based on preliminary data, approximately 10-15 lives were saved, at a cost of well over $100 million.[129-130]

Several studies have identified locations for automated external defibrillators (AEDs) that have been associated with early successful defibrillation.[131-135] These include gaming casinos, airports, nursing homes, and dialysis clinics, among others. Of note, the particular locations where AEDs appear to be cost-effective vary from one country and one community to another. Since 80% of OOHCAs are estimated to take place in the home, the value of a more generalized availability of AEDs in the public domain is currently being studied.[131] The cost-effectiveness and feasibility of AEDs in the home remains unproven; one study showed that survival in residential AED use was only 3.3%.[131] A multicenter North American study examined the effect of AEDs on the likelihood of survival to hospital discharge in OOHCA.[132] Of nine hundred ninety-three units, 85% were placed in a public place, primarily in recreational facilities and shopping malls. The remaining AEDs were placed in patients' homes. The study compared outcome for a lay CPR-only group to that for CPR-plus-AED. There was a 14% survival in the CPR-only group and a 23% survival in the CPR-plus-AED group. Of the survivors, almost all arrests occurred in an area served by the public, rather than the residential, AEDs. A number of communities have equipped police as well as other first-responders with AEDs.[133,134] In Pittsburgh, 183 EMS resuscitations were compared to 118 police-applied AEDs.[135] Mean time to defibrillation decreased from 11.8 minutes in the EMS group to 8.7 minutes in the police group. The earlier shock in the police group was an independent predictor of survival to hospital discharge. Another study from the same authors reviewed ten years of police AED use. Overall, 77% of officers had used an AED, and 45% had witnessed return of spontaneous circulation prior to EMS arrival. Most (65%) did not feel that AED use interfered with other police duties. But all communities are not the same. In a study conducted in suburban and rural Indiana, a police AED program was compared to a standard EMS response. Mean time to arrival by equipping the police with AEDs on scene decreased by 1.6 minutes. Time to first shock decreased by 4.8 minutes. Despite the shorter response and defibrillation times in the police group, survival to hospital discharge was not improved in this study.[136] The author concluded that the lack of improvement in survival was related in part at least to a very limited response to out-of-the hospital cardiac arrest by police officers. Despite having almost half the defibrillator capability in their counties, police responded for traditional EMS in only 6.7 percent of cases. When asked, almost half of the police admitted that they were uncomfortable in the role of treating people in cardiac arrest. They also told investigators that other responsibilities and long travel distances decreased the likelihood that they would respond.

In a report from one suburban community's experience with police AEDs over seven years, survival to discharge for the police group was 9.9% vs. 11.9% in the ALS group, and time to defibrillation was 6.6 minutes vs. 8.4 minutes, respectively. In this study, cost per life-year saved was estimated to range from $1,582 to $16,060, which would be more cost effective than many other standard medical therapies.[136,137]

Authors from Scotland investigated the clinical effectiveness, public health impact, and cost-effectiveness of PAD.[138] Citing a recommendation by the American Heart Association to place an AED in locations where there is an expected rate of one cardiac arrest per defibrillator per five years, these authors estimated that AEDs would only address 1-2% of OOHCAs and would have a minimal impact on population survival and may represent poorer value for money than other interventions.

In another estimate of the cost-effectiveness of AEDs in high-incidence environments (airports, airplanes, casinos), the cost would be "less than the typically acceptable $50,000 per quality-adjusted life- year." The authors, epidemiologists from the University of Washington, concluded that AEDs appear to be cost-effective in locations with high incidences of cardiac arrest.[128-138]

The above data, regarding the crucial role of early defibrillation in survival and the lack of apparent benefit of ALS measures, raise important questions about the best way to allocate EMS resources. Might EMT-Ds (defibrillation) and other first responders (e.g., police, firefighters) prove more cost-effective than paramedic units in improving outcomes of OOHCA? Individual communities and EMS systems will have to weight the evidence and apply it to their own circumstances, but there is ample reason to question our current practices.

Summary

Much of what is currently believed about prehospital care is based on custom and tradition rather than on sound scientific evidence. As our healthcare dollar is stretched to a breaking point, it becomes increasingly crucial that we evaluate the costs and benefits of EMS care in a dispassionate and critical way.

Recent clinical studies suggest that helicopters and ambulance lights and sirens are overused. Further, cardiopulmonary resuscitation is performed poorly and rescue breathing may not be required. Defibrillation is performed too late to benefit patients in many cases. AEDs used by first responders and by the public may be more effective than later defibrillation by paramedics. Pain is managed poorly, if at all, in the prehospital setting.

Emergency physicians and EMS directors are in a unique position at the interface of prehospital and hospital care, and they

are the stewards of a precious and finite set of resources upon which the public safety depends. It is sincerely hoped that the bright light of scientific scrutiny will continue to be shone on many of the current procedures and practices in EMS. Only in this way will the most cost-effective care be rendered for the greatest benefit of the largest number of citizens.

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