

**A Safety
Review
and Risk
Assessment
in Air Medical
Transport**



Supplement to
the Air Medical
Physician Handbook

November, 2002



**AIR MEDICAL
PHYSICIAN
ASSOCIATION**

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November, 2002

To the Air Medical Community,

Safety is a primary concern for all medical transport professionals. Regardless of whether transporting in helicopters, ground ambulances, or fixed-wing aircraft, or if transporting from scenes to hospitals, between hospitals or within a hospital, the movement of patients raises both the risk of medical complications and the risk of transportation accidents and incidents. A great deal of attention has been focused on helicopter incidents and accidents. While improvements in equipment, protocols, training, and operations have occurred, air medical helicopter transport is not as safe as we would like.

In the attached safety report, Dr. Ira Blumen and his team from UCAN provide a fresh perspective on medical helicopter safety statistics and an assessment of risk. They look at the existing data from a variety of viewpoints and have undertaken a unique research project to fill in many of the statistical gaps that previously existed. They compare Helicopter EMS with other aviation data, other routine risks, and provide a basis for future work.

The authors are to be commended for this significant effort. AMPA is proud to make this report available to everyone in the air medical community, and the AMPA Board thanks the many contributors who made this possible.

All of us associated with air medical care should read this report, discuss it with their peers, friends and family, and then read it again. Then they should go to work motivated to improve safety even further. When the second edition of this report is produced, wouldn't it be wonderful to demonstrate lasting improvements in safety, for our community and our patients?

Sincerely,

Kenneth A. Williams, MD, FACEP
President, AMPA
2000-2002

Harry E. Sibold, MD, FACEP
President, AMPA
2002-2004

A Safety Review and Risk Assessment in Air Medical Transport

**Ira J. Blumen, MD
and the
UCAN Safety Committee**

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Air Medical Physician Association



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A SAFETY REVIEW AND RISK ASSESSMENT IN AIR MEDICAL TRANSPORT

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EXECUTIVE SUMMARY

INTRODUCTION

In 1998, helicopter EMS (HEMS) saw the beginning of an alarming accident trend. That year there were eight accidents, followed by ten in 1999, and twelve in 2000. That was a significant increase considering there had been only one accident in 1996 and in 1997 there were a total of three. Questions were raised—and the industry, as well as individual programs, began to look for answers. Is HEMS unsafe? Are HEMS crewmembers at a significantly higher risk for injury or death? Is the information available to answer these questions?

In general, the lack of readily available data made it difficult, if not impossible, to answer these questions adequately. This prompted the University of Chicago Aeromedical Network (UCAN) Safety Committee to begin its own investigation and research in the fall of 2000.

There are many ways to review the safety of air medical transport and to assess the relative risk to its crewmembers. For more than a decade, when our industry or industry observers (e.g., FAA, media, general public) looked at HEMS accident information, the only available information was the number of accidents and fatalities—commonly referred to as the raw data. No one was able to determine if the increase in accidents was simply related to an increase in the number of hours flown, or whether HEMS had indeed become more dangerous.

Our primary investigation began with an extensive review of accident and incident data specific to the HEMS industry. Based on this review, a comprehensive research model was developed to estimate and project exposure data that the air medical industry has stated “does not exist”. Without this exposure data (number of transports and/or the number of hours flown by HEMS), it would be impossible to calculate annual HEMS accident rates and fatality rates or to draw any meaningful conclusions or comparisons.

The study focus next shifted to a comparison of HEMS accident rates and fatality rates to other forms of air travel. Finally, a comparison of air medical transport to other occupations or “routine” risks is made to contrast the fatality rates and the odds of death. To accomplish this, the “population at risk” in HEMS would need to be determined if we were to attempt to make these unique comparisons. This data has never been tracked or even estimated in the HEMS literature.

Upon analyzing HEMS-related risks and assessing the risks faced by air medical crewmembers, this report also identified ways to enhance program (and industry) safety with the hope of reducing our level of accident exposure. Every occupation has inherent risks. Medical professionals and transportation professionals are no different and are exposed to various risks every day.

This research was supported in part through a grant from the Foundation for Air Medical Research and by the University of Chicago Aeromedical Network (UCAN).



AIR MEDICAL PHYSICIAN HANDBOOK

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Being safe does not eliminate risk—it reduces it. This paper provides valuable information regarding risk that will hopefully help each and every air medical program and air medical professional better understand their day-to-day risk. More importantly, they will have information that should help guide the coordination, implementation and evolution of a safety and risk management program, thereby reducing the number of accidents and enhancing survivability.

HEMS DATABASE

This investigation began with a comprehensive analysis of various databases to identify individual HEMS accidents and their corresponding fatalities and injuries. Our research model then enabled us to estimate flight hours, patients flown, and other variables for evaluation. Since 1972, HEMS has flown an estimated 3.0 million hours while transporting approximately 2.75 million patients. In 31 years (through September 2002) there have been 162 accidents involving dedicated medical helicopters and four accidents involving dual-purpose helicopters in the United States. There have been 67 fatal accidents with 183 fatalities, including 144 crewmembers. Since 1998, there have been a total of 50 accidents—nearly 31% of all the accidents we have experienced over three decades.

In the early and mid-1980s, during the HEMS industry's most rapid growth, we experienced an alarming number of accidents. From 1980-1987, there were 54 accidents, averaging 7.7 accidents per year. The late 1980s to mid-1990s showed considerable improvement. From 1987-1997, dedicated HEMS averaged 4.9 accidents each year. From 1998-2001, however, we have seen that average more than double to 10.75 accidents per year. Not since the four-year period of 1983 to 1986 have we seen such a large number of accidents.

The data is not uniformly grim, however. Of the 44 accidents from 1998 to 2001, 15 (34%) resulted in at least one fatality. For the 1980s, our accident database revealed 39% of all accidents resulted in at least one fatal injury, while from 1990-1997, that rate had increased

to 47%. Despite the increase in accidents over the past four years, the percentage of fatal accidents has declined by nearly 30% compared to the early 1980s. In addition, the last four years have seen the lowest consecutive 4-year fatality rate in HEMS history since the early 1980s. The percentage of fatal injuries has also decreased in the 1998-2001 accidents and we see a higher percentage of crewmembers and passengers who sustained no injuries. The fact remains, nonetheless, that since 1990, there has been an average of 2.5 fatal accidents annually, taking the lives of 5 to 6 crewmembers each year.

RECURRENT FACTORS IN HEMS ACCIDENTS

This report summarizes several notable publications, investigations and presentations that analyze and identify key factors related to HEMS accidents. Included in these studies were evaluations regarding incident, operational, and human factor variables. The analyses included the severity of injury, when HEMS accidents occur, condition of light, phase of flight, purpose of flight, the cause of HEMS accidents, pilot experience, aircraft damage and occurrence of post-impact fires. Two studies were also included that analyzed the chain-of-events and problems that led to past accidents. These reports propose interventions intended to prevent future accidents.

A disproportionate number of HEMS accidents occurred during night operations. While an estimated 38% of all HEMS flights were at night, 49% of the accidents over 20 years (1978-1998) occurred during night operations. It was also found that more accidents occurred during cruise (36%) than any other phase of flight.

Scene transports also accounted for a disproportionate number of HEMS accidents. Since 1988, the percentage of scene response flights has averaged 31%, while a total of 42% of the accidents during patient-related missions occurred on scene flights. If all missions had equal risk, then 31% of the accidents should have been on scene missions.

Pilot error was attributed as the direct or indirect cause of HEMS accidents

nearly three times more often than mechanical failure. The studies we analyzed have associated human factors with 65-76% of the HEMS accidents studied. Of the fatal accidents studied, human error was associated with 84%. Human error was a factor in more than two-thirds of the en-route accidents, more than 80% of the accidents during takeoff, and approximately 90% of the accidents during approach and landing.

In 1988, the NTSB concluded that poor weather poses the greatest single hazard to EMS helicopter operations. Subsequent publications found that in the 1980s, 22% of the accidents were determined to be weather-related. In the early to mid-1990s, 32% were related to weather. Tragically, while the total number of accidents went down, the percentage of weather-related accidents had increased by 10%. Since 1998, however, it appears that this trend has dropped significantly to less than 15%. In addition, 88% of the weather-related HEMS accidents occurred at night. Approximately 75% of all weather-related HEMS accidents resulted in fatalities and nearly two-thirds had no survivors.

In-flight collision with an object (CWO) has occurred with 25 HEMS accidents and there has been a dramatic increase in the number of CWO accidents and incidents over the past few years.

More than 25% of the accidents involving CWOs resulted in fatalities. Sixteen (64%) of these CWO accidents occurred during scene response missions. Once again, if all missions had equal risk, 31% of the CWO accidents should have been on scene missions. Instead that percentage rate has more than doubled. It was also identified that more than 40% of all the approach and landing accidents and 50% of all takeoff accidents were CWOs. Unexpectedly, weather has not been identified as a factor in CWO accidents.

Also unexpectedly, pilot fatigue and total hours of flight time do not appear to be significant factors in HEMS accidents. Analysis of HEMS incidents suggests that an IFR rating and currency may be protective in overcoming situations and avoiding accidents. In addition, communications problems, time pressures, and distractions are frequently identified as

contributing risk factors in HEMS accidents and incidents.

The magnitude of injuries and aircraft damage is significant in HEMS accidents. HEMS accidents are more likely to result in fatalities or serious injuries than other helicopter accidents. One study found that main cabin occupants in EMS helicopters have nearly 4.5 times the risk of serious injury (especially back injuries and head injuries) or death in survivable crashes when compared to a comparable population of occupants in the main cabin of non-EMS air taxi helicopters. For front seat occupants, there was no significant difference in injury risk between the two groups. This seemed to support the author's premise that EMS aircraft modifications, which are generally limited to the main cabin, were directly associated with the risk of injury and may contribute to occupant injury and death in otherwise survivable crashes.

Different studies reported the incidence of post-impact fires between 2-15%. Nearly half of the accidents resulted in the destruction of the helicopter. No conclusions, however, can be made regarding single- vs. twin-engine aircraft.

HEMS ACCIDENT AND FATAL ACCIDENT RATES

An important aspect of this study was the determination of HEMS accident and fatal accident rates for the defined study period (1980-2001). Calculations are based upon estimated exposure data, which has been determined through several industry-wide surveys, various calculations and several assumptions, which are stated.

An extensive review of the air medical literature was conducted to determine what data was available. Total flight hours and total patients transported were unavailable for more than 50% of the years reviewed. For various years, published data included: average flight hours per program, total patients transported, average patients transported per program, loaded miles, and average flight hours per patient transport. Unfortunately, there was no data regarding the number of HEMS programs or dedicated helicopters in operation since 1992.

Considering the available vs. unavail-

able information, it was concluded that if the number of programs and helicopters in operation could be determined, then the total flight hours and patients transported could be estimated for the year. Furthermore, an assumption was made that the growth in the HEMS industry has been fairly constant since 1992. It would then be possible to estimate the number of programs and helicopters for the years lacking data.

To determine a fairly accurate number of dedicated HEMS programs and helicopters, several steps were performed. First, a state-by-state survey was posted on the *Flightweb* listserve. The resulting information was supplemented by the AAMS Membership Directory and the "Directory of Air Medical Programs" published in *AirMed*. To further supplement these results, information was obtained from the helicopter manufacturers and a survey of five of the largest HEMS operators was conducted.

It was also determined that our research model should include *total* flight hours in this evaluation. In HEMS, a considerable number of accidents occurred on non-patient missions—including public relations (PR) flights, refueling, maintenance, training, and so on. Personal correspondence with several HEMS programs and operators suggests that non-patient flight time may range from 5 to 15%. PR flights made up approximately half of this for many programs. In an effort to more accurately determine the average number of total flight hours per program, additional information was obtained from the surveyed HEMS operators.

The survey results identified 231 dedicated HEMS programs, operating a total of 377 helicopters (excluding back-up aircraft). Subsequent discussion with several industry leaders and evaluation of information from the aircraft manufacturers suggests that, if anything, these numbers may be slightly underestimated. The helicopter manufacturers estimated that there were 462 medical helicopters (dedicated and backup) in the United States, not including dual-purpose helicopters. With an average of one backup for every 7.1 dedicated helicopters in the combined operators fleets, there are an estimated 53 backup aircraft yielding a total of 430 helicopters. This represents a variation of

approximately 7% fewer aircraft compared to the number of helicopters from the manufacturers' survey. This may also indicate a slight discrepancy in the number of HEMS programs resulting from the Internet survey. In using the lower state-by-state survey results of 377 dedicated helicopters and 231 programs for our calculations, it is realized that the proposed exposure data (flight hours and number of patients transported) may be underestimated. As a result, the calculated accident and fatality rates could be overstated by an estimated 7-10%. This difference, however, does not impact the overall trends identified in HEMS accidents nor the comparison with other aviation operations.

The calculated results show a dramatic decrease in the HEMS accident rate since the mid-'80s. As the raw data would predict, the accident rate since 1998 has steadily increased. However, despite this increase, the rate remains roughly one-third of what was experienced in the early to mid-1980s due to the overall increase in flight hours.

Looking at an average accident rate for 1992-2001, (3.78 accidents per 100,000 flight hours), the average HEMS program flying 911 hours per year, would have one accident over 29.1 years of flight time. If a program flies less, the number of years would presumably increase, and if a program flies more, the time frame would decrease. Another way to propose the likelihood of an accident would be to compare the number of accidents to the number of programs (or helicopters). Again, using the most recent ten years, there has been an average of 7 accidents each year. With 231 dedicated HEMS programs, and assuming all things being equal, we would find a similar prediction of one accident per program every 33 years. If you base this comparison on the number of dedicated helicopters estimated for 2001 (400) rather than programs, the margin now goes up to nearly 57.1 years. Looking at the average number of HEMS accidents (9) for the past five years, we would expect one accident per helicopter every 44.4 years.

The second comparison looks at the fatal accident rate per 100,000 flight hours. Here too, a dramatic improvement is identified since the early and mid-1980s. Our current rate, despite

having gone up slightly over the past few years, is approximately 75% less than our worst years. Once again if we take an average flight program and an average fatal accident rate for the past ten years (1.38 fatal accidents per 100,000 flight hours), we would predict one fatal accident while flying for over 79.3 years. When we focus on the average fatal accident rate for 1997-2001 (1.69) this figure drops to 64.8 years.

The final normalized comparison evaluates the accident rate per 100,000 patients transported.

With a 10-year (1992-2001) average accident rate of 3.89 accidents per 100,000 patients transported and the typical HEMS program flying 882 patients in a year, a program would have one accident while transporting an estimated 25,700 patients over 29.2 years. Calculations for 1998-2001 (4.79 accidents per 100,000 patient transports) resulted in an estimate of one accident while transporting nearly 21,000 patients over a 23.74 year period.

A final annual comparison of HEMS accidents considers the percentage of HEMS programs and helicopters that have sustained an accident. These calculations do not take into account the possibility that an individual program may have suffered more than one accident—which has occurred. Overall, the 22-year average annual percentage calculates to 5.8% of the programs having had accidents between 1980 through 2001. If one considers only the past five years, an average of 4.1% of the programs have had an accident each year. In 1982, an estimated 16.3% of the HEMS programs (8 accidents, 49 programs) were involved in accidents. The safest year was in 1996, when an estimated 0.5 % of the programs had an accident (1 accident, 207 programs).

Calculating the percentage of helicopters that were involved in HEMS accidents each year finds a high of 12.9% of the HEMS aircraft in 1982 (8 accidents, 62 helicopters). In 1996, there was 1 HEMS accident during a year when an estimated 309 dedicated medical helicopters were in operation, for a total of 0.3%. The average percentage over 21 years calculates to 4.4% of the HEMS fleet. Over the past 5 years, this percentage has averaged 2.5% for each year.

HEMS COMPARED TO OTHER AVIATION OPERATIONS

Raw data and normalized statistics are available from the FAA/NTSB for the different types of aviation operations. With the estimated accident and fatality rates per 100,000 flight hours for HEMS, it is now possible to compare various types of aviation in a more meaningful way.

The accident rate for HEMS was dramatically higher than for all other aviation operations during the early and mid-1980s. Beginning in 1987, we see a sharp decline in the HEMS accident rate, which has remained consistently below the accident rates for both general aviation and all helicopter aviation. In addition, from 1987 through 1997, the HEMS accident rate was lower than the overall accident rate for all Part 135 non-scheduled flights 6 of the 10 years. Since 1998, however, the HEMS accident rate has surpassed that of the non-scheduled Part 135 operations each year.

Comparing the average accident rates for the past 20 years (1982–1999), 10 years, and 5 years for the five types of aviation operations, helicopters, and HEMS yield some interesting findings. Even with the high accident rates of the 1980s, the 20-year average for HEMS is below all helicopter operations and general aviation. For the 10-year average, the HEMS accident rate is less than 50% the rate of helicopters and general aviation. For the past 5 years, the average accident rate for HEMS has gone up, but remains significantly lower than all helicopter operations and general aviation.

Initially, the fatality rate for air medical helicopters was equal to or dramatically higher than all other aviation operations. In 1990, however, there were no fatal HEMS accidents. From 1992 to 1997, HEMS was consistently below both general aviation and all helicopter operations in fatal accidents. Since 1998, the HEMS fatality rate has been consistently higher. Looking at the average fatal accident rate for the past 20 years, 10 years, and 5 years for the various aviation operations, HEMS has a higher fatal accident rate than all other aviation during the 20-year period. However, over the past 10 years HEMS has averaged a lower

fatality rate than helicopters and general aviation (Part 91). For the past 5 years, however, the average HEMS fatality rate once again exceeded all other aviation operations.

A COMPARISON OF RISK

In order to assess and compare risk, the relevant figure needed must be in the form of a ratio, fraction, or percentage. To arrive at these figures normalization of the data had to occur and we needed to know two primary numbers. The numerator of the fraction tells us how many individuals doing a particular activity were either injured or killed over a given period of time. The denominator represents how many people were engaged in that activity—the population at risk. By reducing all risks into ratios by utilizing this format we can begin to compare different types of activities and the relative risks.

If one were to try to compare air medical transport to other occupations or “routine” risks to determine either the odds of death in one year or the fatality rate per 100,000 (the most common comparison) we would need to know two things. The first is the number of HEMS crew fatalities per year. The second would be the number of people engaged in HEMS transport (i.e., the number of HEMS pilots and medical crewmembers) for each year. The number of fatalities is known, but the number of crewmembers in HEMS has never been tracked.

For the purpose of this study, the average number of crewmembers per helicopter is estimated to be 22 persons (4 pilots, 6-8 nurses as the primary caregivers, and 10-12 second medical crewmembers). In 2001 there were an estimated 400 dedicated medical helicopters, producing an estimated population at risk of approximately 8,792. Having estimated the number of helicopters for each year in this study, the number of crewmembers can be approximated for each year.

It is important to realize that in estimating exposure in this method, it does so for the *average* crewmember and the *average* flight program. When the raw data is normalized, it does not take into account the *amount* of exposure for an individual during the year. For this por-

tion of the study, calculations are based on the average program, which in 2001 transported approximately 882 patients, flying an estimated 957 hours over the course of the full year, and all crewmembers (pilots and medical crewmembers) flying an equal amount of time.

Fatality and Death Rates

Fatality statistics for HEMS personnel are presented in several different formats. In each case, the number of crew fatalities was determined for each year. To be consistent with statistics from the National Safety Council (NSC), the data was normalized to produce a death rate per 100,000 population at risk for each given year. Over the 21 years reviewed for this portion of the study (1981-2001), the HEMS population has grown from approximately 858 to 8,792. While this growth seems impressive, this is still a very small sampling to translate to a ratio per 100,000. With such a small population base, each fatality has a significant impact on the fatality rate. In this design, the range for the HEMS crewmembers fatality rate is from 0 to 699 per 100,000. With such a wide range, a 22-year average was calculated and used in the various comparisons. The average annual death rate over the 22 years is 196 per 100,000 crewmembers.

Another relationship used to compare the annual number of HEMS crew fatalities is in terms of "odds." For example, in 2001 there were only two crew deaths out of an estimated crew population of 8,792. Looking solely at the numbers, the odds to an individual crewmember suffering a fatal accident that year would be considered to be 1 in 4,396. Contrasting this with what could be considered our riskiest year (1980), there were 6 crew fatalities out of an estimated 858 crewmembers industry-wide. This would correspond to fatality odds of 1 in 143. Excluding 1990 when there were no fatalities, the average odds per year over the 22-year period are 1 in 1,158.

To further illustrate the risk related to HEMS transport, we can compare and contrast the above numbers with other activities, other types of accidents, and other causes of death. Taking into consideration the wide range of fatality rates and odds that we have estimated for each

year in HEMS, the calculated averages are used in subsequent comparisons.

In 1998, the death rate per 100,000 for all accidental deaths was 36.2. Motor vehicle accidents were the highest in this category with 16.1 deaths per 100,000 individuals. When one considers the average annual death rate (192) for HEMS crewmembers over the 22 years reviewed, HEMS is surpassed only by heart disease (268.2 deaths per 100,000) and cancer (200.4 deaths per 100,000) when the data is normalized. The average one-year odds of 1 in 1,158 for HEMS crewmembers is also higher than the one-year odds for all deaths due to injury (1 in 1,796) and all accidental deaths (1 in 2,762).

A final comparison looks at the estimated exposure that will produce a 1 in 1,000 risk of death.

In the 22-year HEMS study period an estimated 3,002,176 total hours have been flown. Adding together the estimated number of crewmembers each year yields a total of 105,922. This corresponds to an average exposure of 28.3 hours of flight time producing the estimated odds of 1 in 1,158. Adjusting the ratio to 1 in 1,000, we get an average exposure of 32.9 hours.

HEMS: The Risk to the Patient

There is some level of risk related to all aspects of healthcare. The results of two comprehensive studies have suggested that between 44,000 and 98,000 Americans die in hospitals each year as a result of medical errors. Normalizing these numbers produces a death rate between 131 and 292 per 100,000 patients due to medical errors. The NSC, however, provides statistics on "complications of surgery/medical care" that is based upon the reported number of deaths compared to the entire U.S. population. Their finding of 1.2 deaths per 100,000 individuals is dramatically different.

While air medical *transport* is not a medical *treatment* and aviation accidents would not be considered a medical error, some could argue that these accidents represent an adverse event in the healthcare environment. In our 22-year study, we estimate a total of 2,745,207 patients

have been flown by HEMS. Over this same time period, 21 patients have lost their lives in HEMS accidents. This corresponds to a death rate of 0.76 per 100,000 patients flown. Based upon these figures, it would appear that there is a far greater risk to the patient of dying from an adverse event while hospitalized than from an accident aboard a medical helicopter.

Occupational Risks: Deaths and Injuries in the Workplace

The NSC reports an average death rate across all industries at 3.8 per 100,000 workers, with mining (21.2) and agriculture (22.5) having the highest rates. With a death rate of 192 per 100,000, the HEMS death rate is approximately nine times greater than the riskiest industries. However, it must be pointed out that this comparison is greatly distorted when you consider the small HEMS "population." Even in 2001, with our largest estimated number of crewmembers, 2 fatalities resulted in a death rate of 23 per 100,000.

RISK MANAGEMENT IN HEMS

A HEMS accident is not caused by a single event, but by a chain of events. In most accidents, numerous risk factors can be identified. Acting on any of these risks and breaking the chain at any point may prevent an accident from occurring. Safety of flight requires the right attitude and active participation. Every pilot, mechanic, medical crewmember, communication specialist, and administrator must be fully knowledgeable of their role and responsibilities. Each must be committed to a safe operation and to ongoing risk management. Nothing takes the place of comprehensive training, proficiency, and sound judgment.

An important training component should be Air Medical Resource Management. The goal of AMRM is to improve crew communications and interactions by addressing teamwork, communication skills, decision making, workload management, situational awareness, preparation and planning, cockpit dis-

tractions, and stress management.

The risks in HEMS should not be underestimated. The cumulative effects of multiple risk factors must be considered when making decisions on each and every transport. Risk management is a major component of the decision-making process. It relies on situational awareness, problem recognition, and exercising good judgment to reduce risks associated with each flight.

Accident prevention must be the objective. But there will be “a next accident.” The air medical community and each program must be certain that the proper aircraft, systems, training, and equipment are in place to enhance the survivability of an accident. A study that evaluated the use of helmets in survivable military crashes found that main cabin occupants with no helmet were at 5 times the risk for a serious head injury and 7.5 times the risk for a fatal head injury than their helmeted counterparts. Another series of U.S. Army studies found that shoulder harnesses were an

important factor in reducing the incidence and severity of serious back injuries. Yet, not every crewmember wears a helmet, not every aircraft is equipped with shoulder harnesses and not every person buckles their seat belt prior to takeoff.

CONCLUSION

Throughout all types of industry, there is generally a 20/80 ratio when it comes to accidents: 20% of all accidents are caused by machine-related problems and 80% of the accidents are caused by human error. This seems to be accurate for HEMS as well. The NTSB commonly identifies “pilot error” as the probable cause in the majority of HEMS accidents. But is it truly *pilot* error? Or have we all failed in some way?

There is no logical reason for the increase in the number of accidents over the past several years. We have regulations, we have safety committees, we

have standards, we have safety summits, we have AMRM, we have surveys and we have reports. We have better aircraft, we have newer technology and we have accreditation. And we have 30 years of experience. What we also **still** have are unnecessary pressures, unnecessary risks, unnecessary distractions, poor communications, complacency—and the same old human errors. What we do **not** have is an excuse!

This report provides a comprehensive review of past studies and offers considerable new information regarding accident rates and risks related to HEMS. This report does not provide the solution to a safer industry. Only you can do that—at your program, on your next flight, on every flight. By providing new information and increasing awareness, we hope to decrease future accidents, and to better educate flight program personnel of the potential risks at hand each and every time the phone rings and the aircraft lifts off.

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A SAFETY REVIEW AND RISK ASSESSMENT IN AIR MEDICAL TRANSPORT

INTRODUCTION

For nearly thirty years, safety has been a focus of committees, articles, lectures, position statements, standards and recommendations within the helicopter EMS (HEMS) industry. Despite the safety programs and safety initiatives industry-wide and program-specific, helicopter EMS accidents continue to occur. HEMS has been credited with saving the lives of tens of thousands of critically ill or injured persons. Tragically, however, there have also been over 150 lives lost due to helicopter accidents in the pursuit of these life-saving missions.

Does the fact that HEMS accidents occur every year suggest that air medical transport is unsafe? Are HEMS crewmembers at a significantly higher risk for injury or death? This report will try to answer these questions by reviewing accident data and trends, identifying potential causes of helicopter accidents and incidents, and reviewing accident and injury rates.

Nothing we do is completely safe. In a 1972 U.S. Supreme Court decision, the court concluded that “safe is not the equivalent of risk free.” There are risks, often potentially serious ones, associated with every occupation, every mile traveled, every food eaten, every hobby, every investment – basically with every action we take. Clearly, some actions are riskier than others and the only way to eliminate risk from any activity would be to avoid participating in it completely.

As health care providers, we are constantly faced with risk. We make patient care decisions based upon the related risks and benefits of any given treatment or transfer. The Emergency Medical Treatment and Active Labor Act (EMTALA) requires that we “inform the individual (or a person acting on the individual’s behalf) of the risks and benefits...” and document that the benefits of transfer outweigh the increased risks to the individual.

In air medical transport safety must be the top priority. We must also consider the risk related to air medical transport—not just to satisfy EMTALA—but to assure that procedures are in place to avoid *unnecessary* risk and that proactive steps are taken to control risk.

This report reviews and summarizes some of the most important publications, presentations, and studies that address various aspects of helicopter EMS accidents. In addition, we describe an extensive research project and our results that enable us to better understand the risks related to air medical transport.

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AIR MEDICAL PHYSICIAN HANDBOOK

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REVIEWING THE DATA

There are many ways to review the safety of air medical transport and to assess the relative risk to its crewmembers. One can look at the safety record and practices of an individual program or look at the industry as a whole. Section 1 of this report looks at the accident and incident data that is specific to the HEMS industry. Another approach is to compare the accident data with that of other forms of air travel and other modes of transportation. This approach is taken in Section 2. Finally, Section 3 compares the identified risks for HEMS to other occupations, high-risk activities, and various routine daily activities.

When looking at accident data, it is common to talk about raw numbers (number of accidents), percentages, or accident rates. But what does that really mean? How can we look at the data, compare statistics, and arrive at conclusions? The Office of System Safety within the Federal Aviation Administration (FAA) has stated that research has shown the importance of comparing like groups when comparing accident data or safety performance. For example, a comparison of one year's HEMS accident statistics with another year's HEMS accident statistics is more likely to be accurate and meaningful than a comparison of general aviation accident data to HEMS data. It may also be helpful at times to look at different categories of aviation to try to draw comparisons and conclusions.

There is no consensus among researchers and participants in the aviation industry as to what constitutes "safety data." In addition, when interpreting comparisons, equivalent types of data are more likely to be accurate than comparisons of different types of data. Therefore, we must first level the playing field in terms of exposure to risk. It is essential that accident and incident data be "normalized." Raw data on accidents and incidents must be converted to accident or incident rates before it can be used for drawing conclusions about safety over time, or to compare different types of aviation, airplanes, pilots, types of operations, and so on.

Comparisons based strictly upon the number of events that occur may not tell the real story. To be meaningful, comparisons must be based upon equal exposure to risk. The longer we are exposed to a particular risk, or the more times we undertake an activity involving risk, the greater the overall risk. However, this alone does not determine total risk. Reduction factors such as experience, proficiency, equipment, and flight conditions can have a significant positive impact on safety.

The FAA and other organizations track aviation data in a number of different ways. The most common method is with respect to flight hours and departures. The data is then normalized in terms of accidents (or fatalities) per 100,000 flight hours or accidents (or fatalities) per 100,000 departures (i.e., takeoffs). In most aviation, unlike

HEMS, takeoff and landings are the higher risk periods. Therefore, short and multiple stop flights are riskier mile-for-mile than long nonstop flights. Airlines generally prefer to focus on accident rates per mile, which makes air travel seem very safe.

The FAA estimates the total flight hours for general aviation based on a survey of a sample of aircraft owners and operators. Scheduled air carriers, on the other hand, must report flight hours, departures, and passengers carried, so their accident statistics may be compared using either departures or flight hours. In the early 1980s when data was kept for HEMS, it was tracked in terms of flight hours and patients transported (which is different than departures). Unfortunately, the air medical transport industry has been unable to develop a consistent method to track its own data – a problem that has recently drawn a great deal of attention. However, numerous calculations are outlined later in this report to make some appropriate comparisons with HEMS.

In much the same way that the FAA normalizes its data, similar strategies must be used to compare the risk of injury or death. To assess the magnitude of risk, we must again normalize the data in some fashion. In this case, the relevant figure is in terms of a ratio, fraction, or percentage. By reducing all risks to a common format, we can begin to compare different types of activities and the relative risks. The larger the percentage, the riskier the activity.

SECTION 1: AIR MEDICAL ACCIDENTS AND INCIDENTS

This section presents an overview of HEMS accidents and reviews several notable investigations. The first, from a series of articles written by Rick Frazer and published in *AirMed*, presents a 20-year review of air medical accidents and specific types of accidents. Second is a 1988 report of 59 HEMS accidents (1978-1986) by the National Transportation Safety Board (NTSB). The next study by Patrick Veillette is from the Flight Safety Foundation (April 2001) and reviews 87 accidents from 1987 through 2000. A 1994 study by the NASA-Ames Research Center is then summarized which evaluates air medical

incidents, rather than accidents. The final report in this section is the "Air Medical Accident Analysis" which analyzed past accidents and identified interventions to prevent future accidents. This section concludes with a review of the 1998-2001 HEMS accidents and finally with a comparison of HEMS accident rates, which are based upon available data, research, several necessary assumptions, and various calculations.

BACKGROUND

Air medical transport began in the military, which laid the groundwork for

the air transport of critically ill and injured patients. The first civilian air medical operations were established in the late 1960s in the form of dual-purpose programs, which combined the function of public safety agencies with EMS missions. In 1972, the first fatal EMS-related accident occurred within one of these dual-purpose programs. That same year, St. Anthony's Hospital in Denver established the first dedicated hospital-based HEMS program.

In the 1970s and '80s, various publications and organizations tracked the growth of the dedicated helicopter EMS industry. The number of dedicated pro-

grams grew slowly in the '70s, but gathered significant momentum in the early 1980s. In 1981 there were 45 programs and by 1986 the industry had almost tripled to 129 programs. Unfortunately, this was accompanied by an increase in the number of air medical accidents.

In the late 1980s new trends were seen. More programs added a second helicopter to their operation, while other programs closed down. In many areas competition was fierce. By 1990 there were 174 programs operating 231 helicopters.

In the '90s, air medical programs and industry-wide statistics became increasingly difficult to track. While new programs started and helicopters were added to many established programs, others merged operations and still more closed. Fixed-wing (airplane) air medical transport continued to grow and became an integrated component of the industry. During this time, the industry did not maintain an accurate census. In addition, industry-wide data was not kept as to the total number of patients transported or the total number of hours flown. The importance of this data will become evident later in this report.

AN OVERVIEW OF HEMS ACCIDENTS: 1972 TO 2002

This research study, developed by members of the UCAN Safety Committee, began with a comprehensive review of numerous databases to identify HEMS accidents and their corresponding fatalities and injuries. Since the introduction of civilian HEMS in 1972, the United States has experienced 162 accidents involving dedicated medical helicopters and four additional accidents involving dual-purpose aircraft. Of these accidents, 67 have resulted in at least one fatality. Figure 1-1 shows the total number of HEMS accidents and fatal accidents (an accident where at least one occupant died) broken down for each year since 1980. As the lines in gray show, until the last few years, the highest number of accidents occurred in the mid-1980s—the same time that the industry experienced its most rapid growth. The early and mid-1990s showed an improvement, but unfortunately, 1998–2001 showed a steady increase in accidents.

Fortunately, the number of fatal accidents did not rise at the same rate.

The NTSB defines an aircraft accident as “an occurrence associated with the operation of an aircraft which takes place between the time any person boards the aircraft with the intention of flight and all such persons have disembarked, and in which any person suffers death or serious injury, or in which the aircraft receives substantial damage.” An incident means “an occurrence other than an accident, associated with the operation of an aircraft, which affects or could affect the safety of operations.” The NTSB also classifies the severity of various injuries that may occur from an accident as fatal (“any injury which results in death within 30 days of the accident”), serious, minor, or none.

When reviewing any accident database or report, it is essential to know the inclusion and exclusion criteria for the data that is used. There are many agencies, organizations, and individuals who maintain and track data regarding HEMS accidents and incidents. There is not always agreement on what should be included in a report or study. Some studies look at only patient missions. Others will look at non-patient missions as well. Some reports include fixed-wing (FW) as well as rotor-wing (RW) and some databases include incidents as well as accidents. An accident database may include only dedicated air medical services, while others might include dual-purpose (e.g.,

police, fire) aircraft. There is no right or wrong way, but it is essential to know what is included in each statistical review.

The accidents listed in Figure 1-1 are the end product of a detailed review of various personal databases, publications, and Internet websites. In numerous cases, available information was insufficient to determine inclusion vs. exclusion into our own database. To clarify the accident information, direct communication by telephone or email was also employed. Included in this table are dedicated medical helicopter accidents that occurred on either patient or non-patient missions. Also included are known accidents involving dual-purpose helicopters (a total of four accidents and nine fatalities) that crashed during medical missions. Fixed-wing air medical accidents, military accidents and international accidents have not been included in our database or statistical analysis.

Our review found 162 HEMS accidents in which we identified a total of 183 fatal injuries. Accidents have taken the lives of pilots, nurses, physicians, paramedics, respiratory therapists, patients, police officers, fire fighters, and observers. There were also 60 individuals who suffered serious injuries and 73 with minor injuries. A total of 195 people were not injured. Figure 1-2 shows a breakdown for injuries and fatalities for each year in our study. We have also included year-to-date information for 2002.

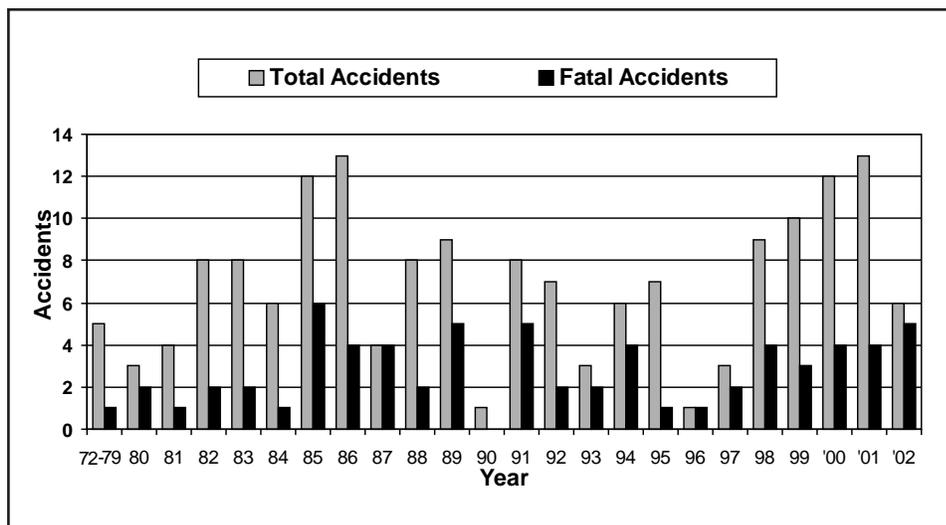


Figure 1-1: HEMS Accidents and Fatal Accidents, 1972–2002* (*through 9/30/02)

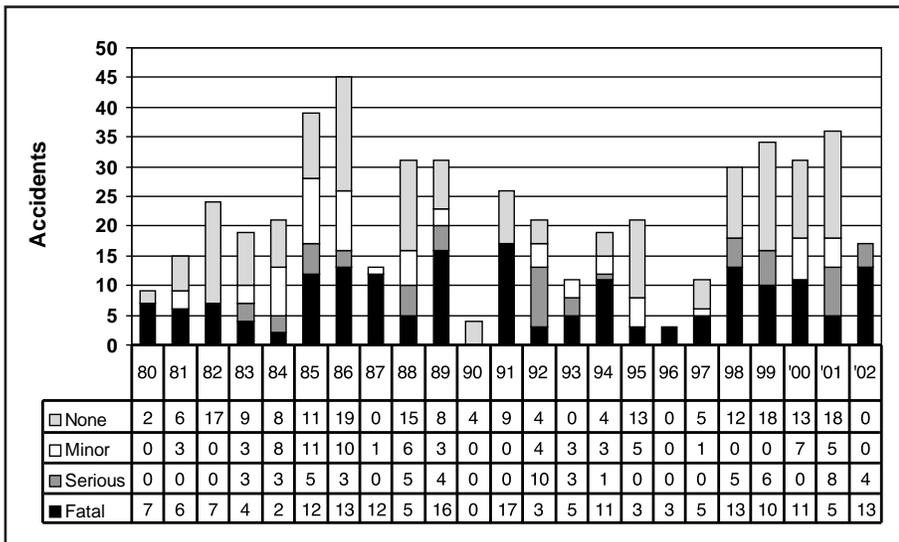


Figure 1-2: Fatalities and Injuries, 1980–2002* (*as of September 30, 2002)

not necessarily correspond to the number of accidents previously presented since this study also included over a dozen fixed-wing accidents and several accidents that did not meet our inclusion criteria.

Severity of Injury

Frazer reported that 406 individuals were involved in HEMS accidents. There were 168 fatalities, 50 serious injuries, and 61 minor injuries. There were 127 who sustained no injury. Figure 1-4 shows the trend over the years with regard to fatalities and Figure 1-5 summarizes the severity of injuries for all the reported accidents.

AIR MEDICAL ACCIDENTS: A 20-YEAR REVIEW

Perhaps the most complete analysis of air medical accidents is represented in a series of *AirMed* articles by Rick Frazer. The first of the series was published in the September/October 1999 issue. The article “Air Medical Accidents—A 20 Year Search for Information” presents a review 104 rotor-wing, 15 fixed-wing, and three public EMS accidents for a total of 122 accidents between 1978 and 1998. Included were only accidents that occurred to dedicated medical transport services, not to private or public aircraft that may also perform an occasional medical transport.

This study included only accidents as defined by the NTSB. In follow-up to this article, Frazer looked at specific types of accidents—those related to weather, collisions with objects, and maintenance.

Accidents and Fatal Accidents

While the number of HEMS accidents is a critical consideration, even more important is the high number of fatal accidents seen in HEMS. In the 1980s, 42% of all accidents resulted in at least one fatal injury. Between 1990 and 1998, this percentage rose to 56%. Figure 1-3 compares the number of accidents to fatal accidents for 1978 through 1998—the years included in Frazer’s report. It is important to note that these numbers do

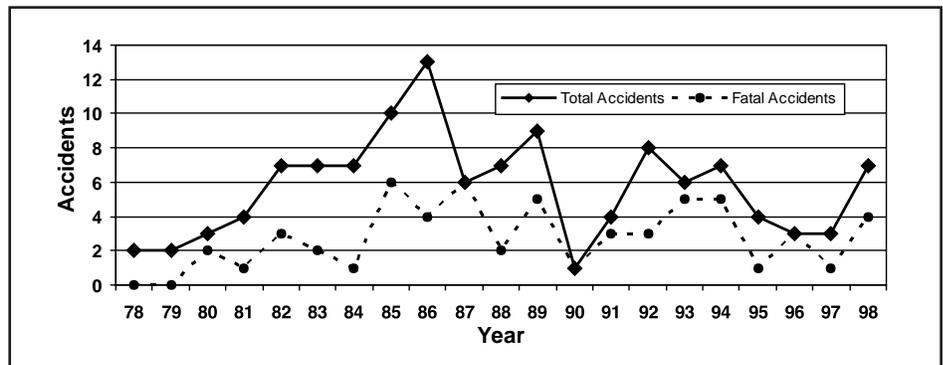


Figure 1-3: Accidents and Fatal Accidents, 1978—1998

Adapted from: Frazer, *AirMed*, Sept/Oct 1999

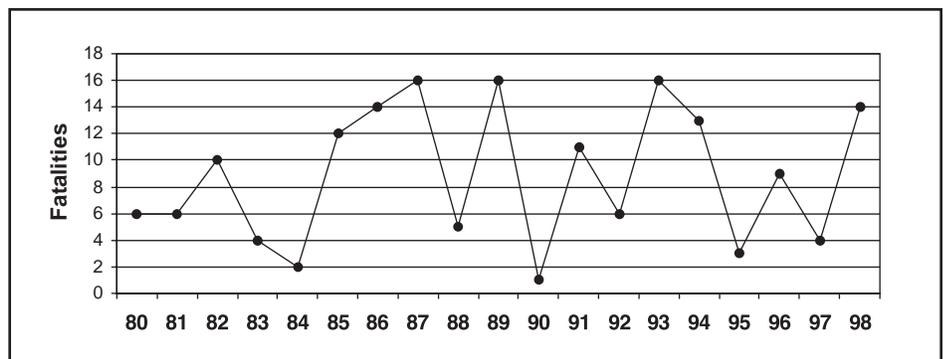


Figure 1-4: Fatalities per Year

Adapted from: Frazer, *AirMed*, Sept/Oct 1999

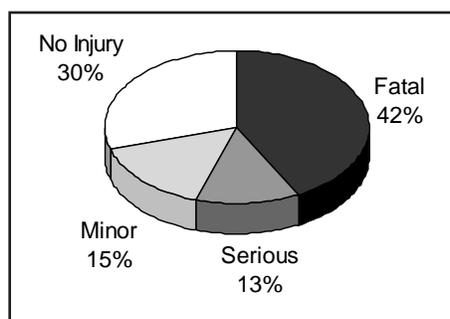


Figure 1-5: Severity of Injuries — Air Medical Accidents, 1980—1998 (n=397)

Adapted from: Frazer, *AirMed*, Sept/Oct 1999

When Do HEMS Accidents Occur?

When an accident occurs is an important consideration when looking at the safety of flight and may provide insight to the severity of injuries and the high number of fatalities. The time of day (i.e., day vs. night), type of mission (i.e., the purpose of the HEMS flight), and the phase of flight are all-important factors to evaluate.

Condition of Light

It would appear in Figure 1-6 that EMS accidents showed no significant preference for day vs. night operations. However, the 1999 *AirMed* Transport Survey indicates that only 38% of all HEMS flights were at night. Since 1988, the range has been between 35 to 42%, with an average of 38%. In contrast, 49% of the HEMS accidents over 20 years occurred during night operations. Of interest, Frazer's report identifies three noticeable peak accident times: noon to 1pm, 6-7pm, and 10-11pm.

Phase of Flight

The phase of flight that the aircraft was in at the time of the accident is reported in the NTSB reports. This includes takeoff, landing, cruise, hovering, maneuvering, or taxiing. Data for both helicopter and fixed-wing accidents are provided in Figure 1-7.

As previously mentioned, in most aviation operations, aircraft are more prone to incidents or accidents during takeoffs and landings. This was not found to be the case with HEMS accidents. More accidents occurred during cruise (36%) than any other phase of flight. Accident reports frequently identify entry into inadvertent instrument meteorological conditions (IMC) as a contributing factor for many of the accidents (i.e., flying into poor weather conditions).

Purpose of Flight

The purpose of flight for HEMS accidents was tracked by Frazer in his article. He divided flights into two major categories: patient-related and non-patient related. He further divided the patient flights into scene vs. interhospital; and

finally determined if the aircraft was enroute to the patient, had a patient on board, or if the aircraft was returning from a patient flight (i.e., the third "leg" of a transport). Evaluating these components of HEMS transports might indicate a particular interval when more accidents seemed to occur. Figure 1-8 depicts the various purposes of flight and the different legs of patient transport.

Trying to determine the most dangerous flight or leg of a patient transport from Figure 1-8 may be difficult. More accidents occur on the transport to the patient than on either remaining leg. However, if the helicopter was transporting the patient back to its base facility, there would be no third leg of a transport. The pie charts in Figures 1-9 to 1-12 look at the percentage of accidents that occurred on the various types of missions and then each leg of the transport.

In general, it appears that approximately 50% of all accidents occur enroute to the patient and 50% on the way back. Of note is the fact that 85 of the 104 HEMS accidents that occurred were on patient-related missions, of which 36 were scene responses. This corresponds to 42% of the accidents during patient-related missions. Referring

again to the "2000 Annual Transport Statistics," scene missions accounted for only 28% of all patient transports. Since 1988, the percentage of scene response flights has ranged from 25% to 36%, with an average of 31%. If all missions had equal risk, then 31% of the accidents should have been on scene missions. Scene missions have always been perceived as the most difficult and potentially the most dangerous in HEMS and this data would seem to confirm this. However, the fact that a higher percentage of the accidents occur after the patient has been picked up rather than enroute to the scene (56% to 44%) further confounds this theory.

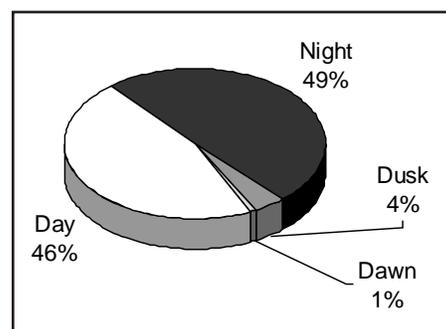


Figure 1-6: Day vs. Night HEMS Accidents, 1978-1998 (n=107)
Adapted from: Frazer, *AirMed*, Sept/Oct 1999

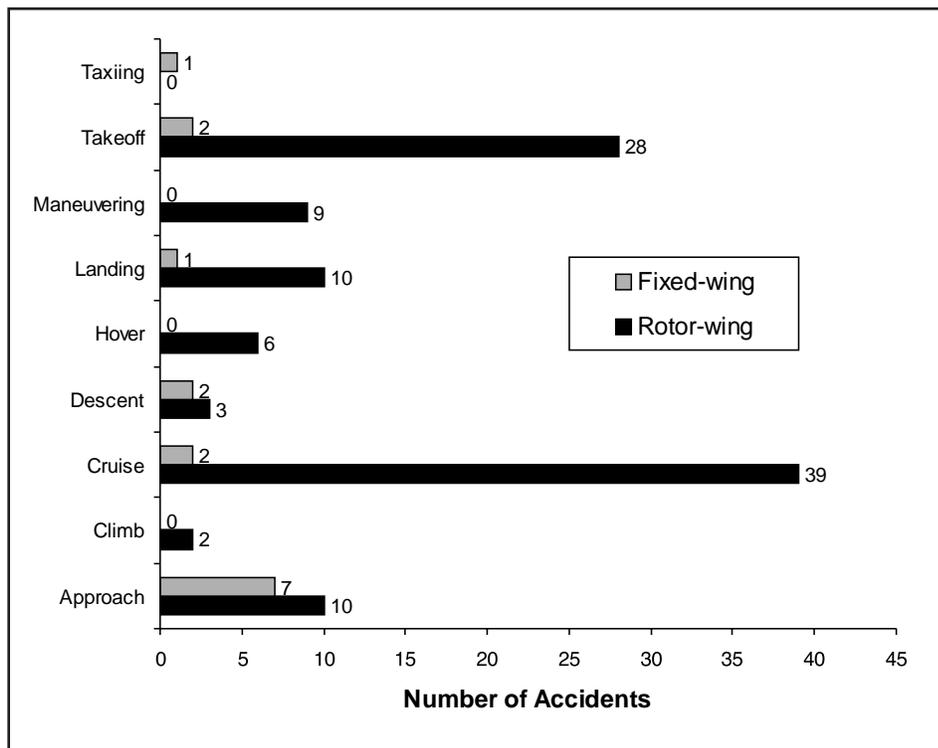


Figure 1-7: Phase of Flight

Adapted from: Frazer, *AirMed*, Sept/Oct 1999

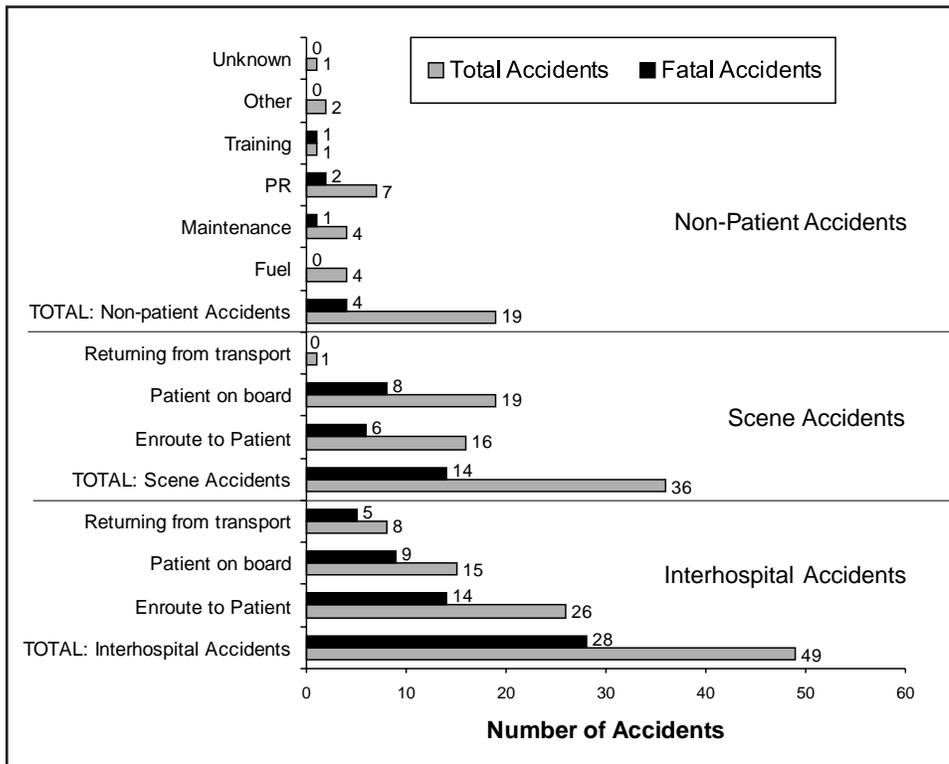


Figure 1-8: Phase and Purpose of Flight

Adapted from: Frazer, *AirMed*, Sept/Oct 1999

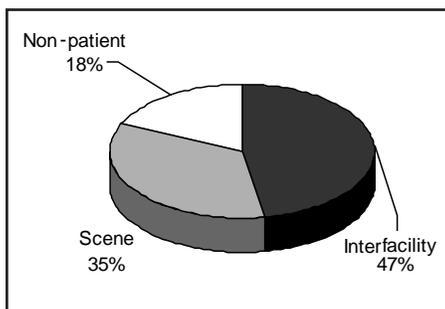


Figure 1-9: All HEMS Accidents (n=104)

Adapted from: Frazer, *AirMed*, Sept/Oct 1999

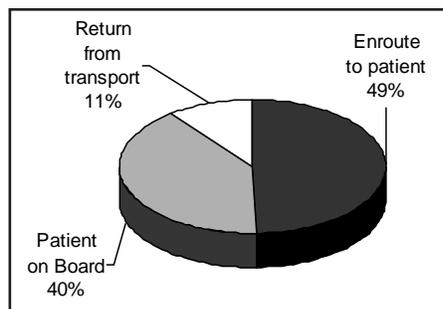


Figure 1-10: Accidents During All Patient Transports (n=85)

Adapted from: Frazer, *AirMed*, Sept/Oct 1999

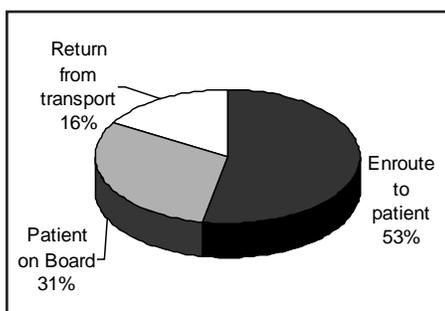


Figure 1-11: Accidents During Interhospital Transports (n=49)

Adapted from: Frazer, *AirMed*, Sept/Oct 1999

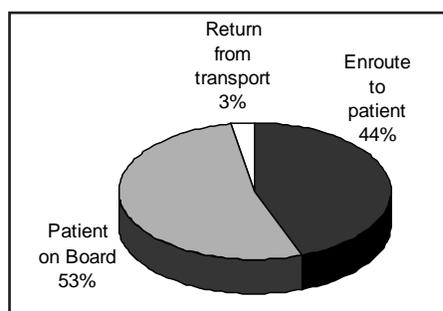


Figure 1-12: Accidents During Scene Transports (n=36)

Adapted from: Frazer, *AirMed*, Sept/Oct 1999

The Cause of HEMS Accidents

It is rare that a single isolated event causes an accident. Instead, it is generally agreed that a set of contributing factors and circumstances usually lead to a final event that results in the accident. The NTSB investigations, however, usually conclude that an accident occurred as a result of one of two probable causes—either pilot error or mechanical problem. The NTSB may also list the case as “Unknown” or “To be Determined.” At times, the NTSB may list more than one cause for a particular accident.

Identifying and specifying the cause of an accident may not be easy, even after a thorough and detailed investigation. In one HEMS accident, after an engine problem developed, the pilot shut down the wrong engine. The result was a fatal accident. Should this accident be attributed to pilot error or a mechanical failure?

The two main categories—pilot error and mechanical failure—are divided into more specific causes as determined in the final report of the NTSB. In his report, Frazer listed the causes of 104 helicopter accidents. A total of 68 (65%) were pilot error and 26 (25%) were mechanical failure. The remaining accidents were unknown (3) or still to be determined (9). Figure 1-13 lists the identified causes of the rotor-wing accidents.

Weather-related Accidents

Weather-related accidents remain an all too familiar theme in HEMS. Frazer’s 1999 report listed 23 such accidents, of which 17 were fatal. In the May/June 2000 issue of *AirMed*, Frazer’s article “Weather Accidents and the Air Medical Industry” updated his weather-related accident data. With this article, Frazer’s accident database has increased from 122 to 136 helicopter and fixed-wing accidents, with 121 final reports available. There are now 31 weather-related accidents in his database, equal to 26% of the accidents with final reports. Of these 31 accidents, 25 were rotor-wing and 6 were fixed-wing.

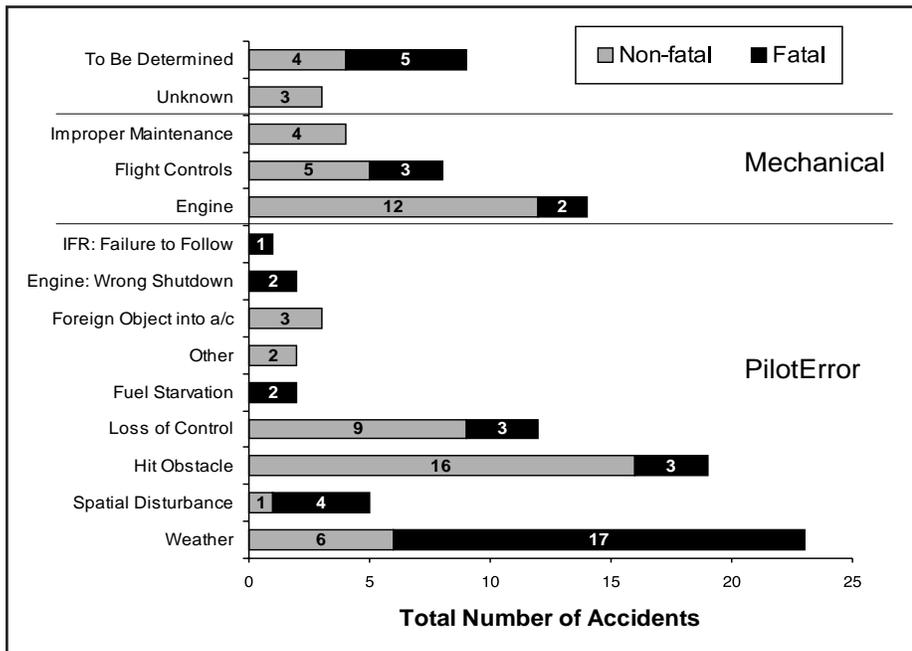


Figure 1-13: HEMS Accidents by Cause Adapted from: Frazer, AirMed, Sept/Oct 1999

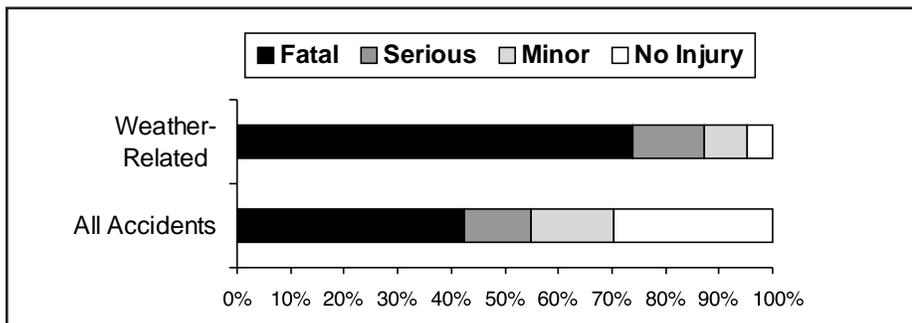


Figure 1-14: Severity of Injuries—All Accidents vs. Weather-related, 1982–1998 (All accidents: n=397; Weather-related accidents: n=103) Adapted from: Frazer, AirMed, Sept/Oct 1999 and Frazer, AirMed, May/June 2000

Background Information: Weather Limitations

Subpart D of the FAA Part 135 regulations (sections 135.201 to 135.205) outlines the FAA's operating limitations and weather requirements, including minimum altitudes and visibility for "air taxis." In addition, the Federal Aviation Regulations (FARs) under Part 135 require that Air Taxi Operators set their own weather minimums in Chapter 4 of their Operations Manual. The weather minimums describe the minimum ceiling (lowest cloud height above the ground that covers 5/8 or more of the sky) and the minimum visibility the pilot must have to accept a flight.

The ceiling and visibility requirements generally vary for day vs. night flight and for local vs. cross-country flights. The definition of "Local" may also vary from 50 to 100 miles or more. Many state regulatory agencies and organizations may also set minimums for ceiling and visibility. The Commission on Accreditation of Medical Transport Systems' weather guidelines are:

Condition	Area	Ceiling	Visibility
Day	Local	500'	1 mile
Day	Cross Country	1000'	1 mile
Night	Local	800'	2 miles
Night	Cross Country	1000'	3 miles

In the 1980s, there were a total of 73 accidents, of which 16 (22%) were determined to be weather-related. In the 1990s the number of accidents (with final reports) had decreased to 44, with 14 (32%) related to weather. Tragically, while the total number of accidents went down, the percentage of weather-related accidents increased by 10%.

Looking at when these weather-related accidents occur is also of importance. Previously it was noted that nearly half of all HEMS accidents occurred at night (53 of 107). In comparison, Frazer's article in 2000 found that 22 of 25 (88%) weather-related HEMS accidents occurred at night. Fixed-wing weather-related accidents remained at 50%, even at night.

Of the 25 weather-related helicopter accidents, 17 (68%) of the accidents were interhospital and 8 (32%) were scene missions. This correlates well to the overall percentage of scene missions for HEMS program, which was previously noted at 31%. Of interest, there is a noted decrease in the percentage of scene accidents when comparing weather-related accidents (32%) to all patient-related mission accidents (42%).

The outcome of weather-related accidents is also very dramatic. Nineteen of the 25 HEMS accidents (76%) had fatalities and 64% had no survivors. Compared to all accidents in Frazer's 1999 study, only 45% (55 of 122) of all accidents resulted in at least one fatality. In addition, 76 of 103 (74%) of the souls on board sustained fatal injuries, 14 had serious injuries, 8 suffered only minor injuries, and 5 had no injury. Figure 1-14 shows the relative comparison (percentage) of the severity of injuries in the weather-related accidents reported in 2000 to the total accidents reported by Frazer in 1999.

In general, the cause of the weather-related accidents does not appear to be a pilot's disregard for established weather minimums at takeoff. Instead, it is the pilot's encounter with instrument meteorological conditions (IMC) en route. In the narratives of the 25 helicopter accidents, Frazer noted that 10 pilots were turning around, one was circling, six continued into IMC and one was on an IFR flight plan. The pilots' actions were unknown in 7 cases.

There are three types of weather-related accidents:

- **Controlled Flight Into Terrain (CFIT)** refers to an event that normally occurs in IFR conditions or at night. Loss of situational awareness is apparent in all CFIT accidents.
- **Loss of Aircraft Control** corresponds to an event in IFR conditions when the pilot is unable to maintain control of the aircraft by reference to the flight instruments. Spatial disorientation is the primary cause and is often the result of continued VFR flight into IFR conditions.
- **In-flight Collision with an Obstacle** is an event that normally occurs in conditions of restricted visibility when the pilot is unable to see an obstacle or the terrain in time to avoid a collision. This is the most common weather-related accident for helicopters.

Collision with Objects

An in-flight collision with an object (CWO) may occur in various conditions and settings. Frazer's 1999 study identified 19 HEMS accidents that resulted from a CWO. In his 2001 report "Air Medical Accidents Involving Collisions with Objects," the database increased from 122 to 150 fixed-wing and rotor-wing accidents, 27 of which involved a CWO. This represented a dramatic increase in the number of CWO accidents, as there had been a total of 8 such accidents during the 9-year period from 1990 to 1998, while in 1999 and 2000 alone, there were 7 CWO accidents. Frazer also identified 21 CWO incidents over the past 5 years.

Twenty-five of the CWO accidents in Frazer's report involved rotor-wing aircraft. Frazer observed that weather was not considered to be a factor in any of these. Sixteen (64%) of the accidents occurred during scene response missions—all occurring at or near the landing zone. Eight (32%) were during some phase of flight during interhospital transports, four of these at or on the hospital helipad. The remaining CWO was during a maintenance flight. Of the 24 patient missions, 12 occurred on the way to pick up the patient, 9 occurred with the patient on board, and 3 were returning after a

patient flight. As previously presented, scene response flights account for an average of 31% of all patient transports. If all missions had equal risk, 31% of the CWO accidents should have been on scene missions. Instead that percentage more than doubles.

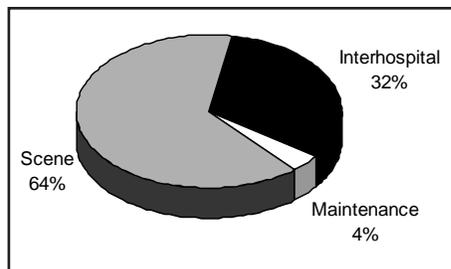


Figure 1-15: Type of Mission—CWO Accidents (n=25)

Adapted from: Frazer, *AirMed*, May/June 2001

Wires are the most common objects with which helicopters collide. Of the 25 CWO accidents, 9 were wire strikes. Frazer classified four of the CWO accidents as "other," which included the ground, rocks, and in one incident, a barge. There were three CWOs with trees, three with ground obstacles (lamp posts, fencing, etc.), two with support cables to towers and one each with a building, hangar, hospital helipad, and tower.

As expected, collisions with objects occur most commonly on takeoff and landing. The time of day also varies, but yielded some interesting results as seen in Figure 1-16.

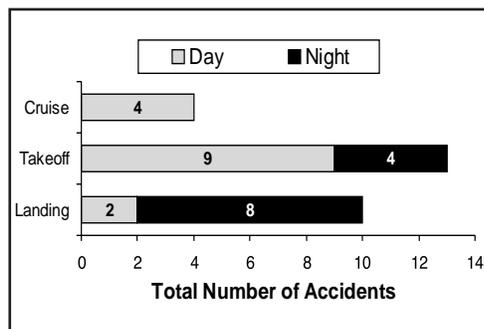


Figure 1-16: Phase of Flight and Lighting Conditions

Adapted from: Frazer, *AirMed*, May/June 2001

Since most of the CWO accidents occur during takeoff and landing, it follows that the aircraft are at a lower altitude and slower speed.

Accordingly, only 7 of the 25 (28%) RW accidents resulted in a fatality. Of the 4 cruise accidents, 3 were fatal. All the cruise CWO accidents identified by Frazer were RW, all were during the day in clear weather, and 3 were on the return flight home.

Frazer concludes his 2001 study with recommendations for comprehensive training and procedures for flight personnel to enhance safety and reduce the likelihood of CWO accidents. "Medical personnel should be taught how to spot obstacles, and detailed procedures should be in place on how to communicate—down to the exact words the crew uses—an immediate threat versus an obstacle in the distance." In addition, Frazer suggested the disassociation of Landing Zone (LZ) and safety training from marketing and emphasize the importance of ongoing safety education as a separate, budgeted activity.

Maintenance-related Accidents

The data presented in Figure 1-13 represent Frazer's 1999 study, which showed 26 maintenance-related accidents (MRAs) out of 122 total accidents. In the May/June 2002 *AirMed*, Frazer examined the "Air Medical Accidents Attributed to Maintenance." A total of 34 such accidents were identified in the 2002 report which now includes 143 rotor-wing and 18 fixed-wing MRAs. Thirty of the MRAs were rotor-wing and four were fixed-wing. Excluding 11 accidents that lacked NTSB final reports, Frazer concluded that 23% of all accidents were maintenance-related.

Frazer separated the probable cause of the MRAs into five different categories. Over the 24-year period, there were a total of 17 engine-related accidents, 15 of which involved rotor-wing aircraft. Twelve involved single-engine aircraft and three involved twin-engine aircraft. Even though the engine-related accidents represent half of all MRAs, Frazer observed that engine-related incidents happen much

more frequently. Fortunately, due to the skills of the EMS pilots, the vast majority of these incidents do not result in accidents.

In 11 of the final NTSB reports, Frazer found “inadequate or improper maintenance” as a factor in the accident. In addition, there were five reports that identified “manufacturer design” or “inadequate aircraft component product/design” as a factor.

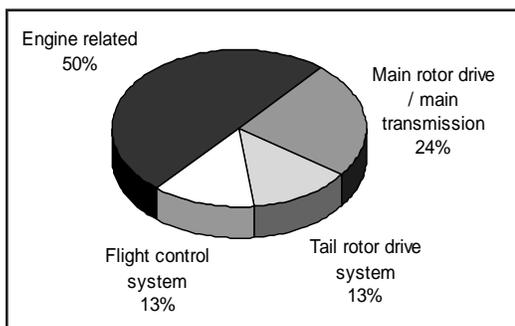


Figure 1-17: Probable Cause of Maintenance-related HEMS Accidents (n=30)
Adapted from: Frazer, *AirMed*, May/June 2002

As Figure 1-18 shows, nearly 50% (16 of 34) of all rotor-wing and fixed-wing MRAs occurred during cruise. Interhospital transport accounted for nearly two-thirds of the accidents.

Pilot Experience

Experienced pilots don't make mistakes or have accidents. Or do they? Unfortunately, flying with “high-time” pilots does not necessarily guarantee that an accident won't happen. Much of the HEMS industry requires a minimum of 2,000 hours of flight time before assuming command of a medical helicopter. In addition, most operators, organizations, and even some states dictate a specific number of flight hours in type-specific aircraft before a pilot can fly medical missions.

Figure 1-19 shows the flight experience of the pilots involved in HEMS accidents. Unfortunately, there is no data available regarding the average number of flight hours for all HEMS pilots or the percentage of all HEMS pilots that would fall into each category listed in Figure 1-19. Of the pilots involved in HEMS accidents, the lowest total hours were 1,432, while the highest was 14,000. More importantly perhaps, in 27 of the 122 accidents (22%), the pilot had fewer than 200 hours of flight time in the make and model of the aircraft they were flying at the time of the accident. Eighteen (15%) had fewer than 100 hours and one had only three hours.

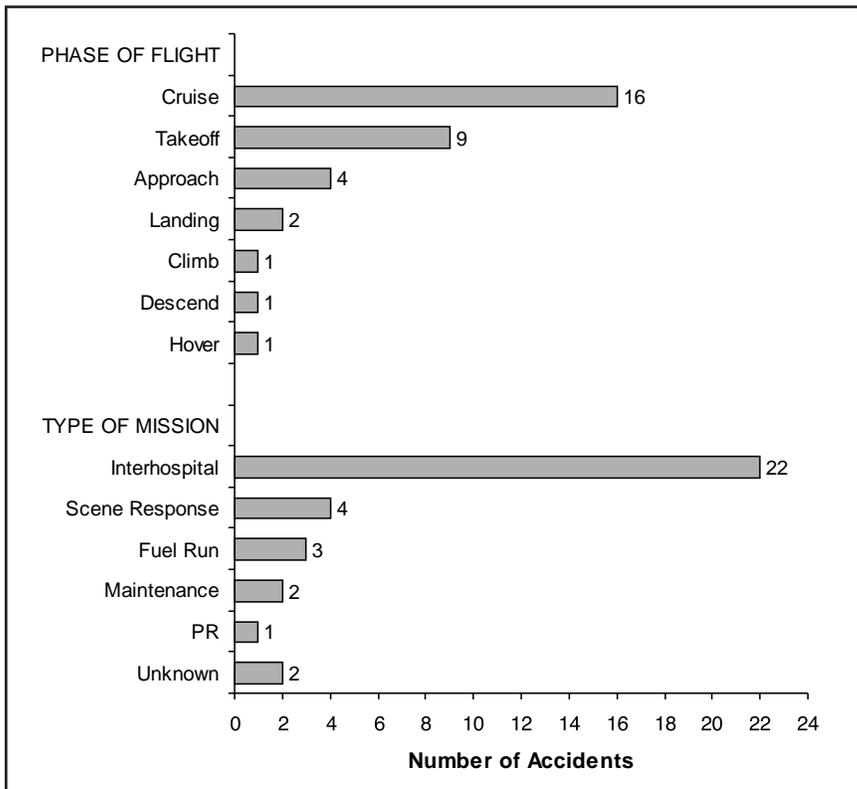


Figure 1-18: Maintenance-related Accidents—Phase of Flight and Type of Mission
Adapted from: Frazer, *AirMed*, May/June 2002

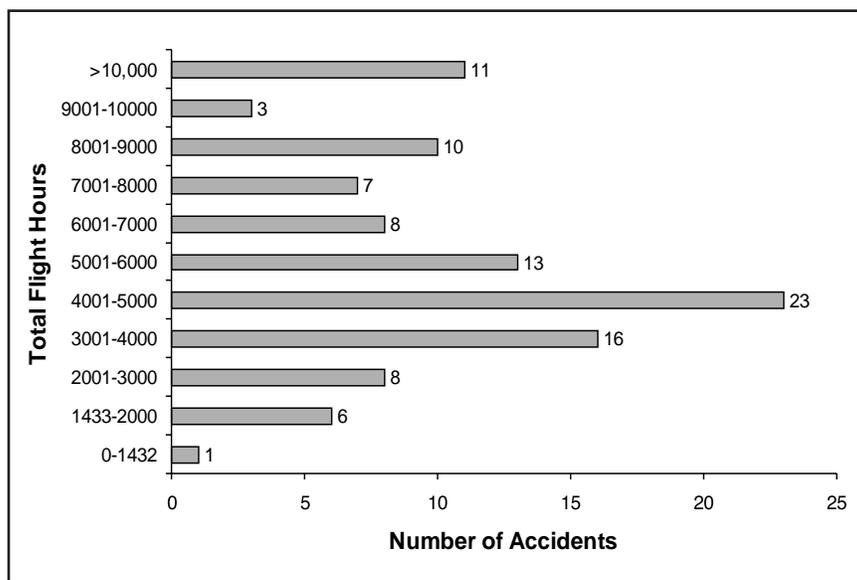


Figure 1-19: Pilot Experience
Adapted from: Frazer, *AirMed*, Sept/Oct 1999

Engines

A frequent debate with regard to safety is whether “two engines are better than one.” Of the 17 accidents attributed to engine problems, 12 were single-engine and 3 were twin-engine. However, this does not

help resolve the debate, knowing that in the early years of HEMS, most helicopters were single-engine. Therefore, more of the accidents were in single-engine aircraft. In another section of this report is accident data collected by the Helicopter Association International (HAI)

comparing single- vs. multi-engine helicopters which shows a lower accident rate overall for multi-engine helicopters.

Aircraft Damage and Post-Impact Fire

In the NTSB accident reports, aircraft damage is classified as either destroyed or substantial. Of the 122 air medical transport accidents, 70 (57%) aircraft were destroyed and 51 (42%) were reported as having suffered substantial damage. At the time of Frazer's report, one was listed as unknown. Of note, when looking only at the weather-related accidents, 84% of the helicopters and 100% of the fixed-wing aircraft were destroyed.

Post-impact fire is often perceived as another major concern with regard to HEMS accidents. Frazer's data, seen in Figure 1–20 shows that the vast majority of HEMS accidents do not result in a post-impact fire. While fixed-wing aircraft accidents resulted in fires 67% of the time, only 15% of helicopter accidents sustained post-impact fires. There were, however, six accidents that had an in-flight fire.

NATIONAL TRANSPORTATION SAFETY BOARD SAFETY STUDY: COMMERCIAL EMERGENCY MEDICAL SERVICE HELICOPTER OPERATIONS – 1988

Frazer's 20-year review provides a comprehensive look at the HEMS industry and our accident history from 1978 to

1998. This next report by the National Transportation Safety Board (NTSB), however, looks at a narrower time frame. When published in 1988, it became the hallmark safety study at the time of our industry's highest accident and fatality rate.

During the early 1980s, the increased use of helicopters as air ambulances came at a high price. While the number of flight programs more than tripled from 1981 to 1986, the NTSB began to identify a significant rise in the number of accidents. In 1984 there were 7 HEMS accidents. The next year, there were 11 and in 1986, there were 14 accidents investigated by the NTSB. These 14 accidents corresponded to 9 percent of the total commercial HEMS industry operating that year. As a result, a formal safety study was undertaken by the NTSB and published in 1988.

The NTSB studied 59 commercial HEMS accidents that occurred between 1978 and 1986. Nineteen of these accidents resulted in fatalities, taking the lives of 53 people (19 pilots, 28 medical personnel, and 6 patients). A total of 47 accidents were on patient mission flights and 12 while on other activities (refueling, PR, training, etc.). However, in the calculation of accident rates, the NTSB only included the 47 "mission" accidents. In addition, this study did not include any public-use aircraft.

According to the NTSB report, from 1980 through 1985, HEMS had an estimated accident rate of 12.34 accidents per 100,000 hours of flight, nearly double that of nonscheduled Part 135 ("air taxi") helicopter operations (6.69/100,000 flight hours). They also determined that the fatal accident rate

for HEMS was 5.40—nearly 3.5 times higher than the 1.60 determined for other nonscheduled Part 135 helicopter operations.

The NTSB identified four major factors in the 59 HEMS accidents studied. Human error (i.e., pilot error) was attributed as the cause, directly or indirectly, of the majority of these accidents (68%). Weather was the second most common cause of these HEMS accidents (30%), followed by mechanical failure (25%), and obstacle strikes (20%). The weather-related accidents accounted for 61% of the fatalities and the NTSB concluded that poor weather poses the greatest single hazard to EMS helicopter operations.

The NTSB report identified several disturbing trends involving HEMS operations. They were concerned that the rapid increase in the number of programs and resulting competition could result in a focus on transport volume instead of flight safety. Pilots might feel self-imposed or externally imposed pressure (i.e., by management) to accept and complete flights despite marginal operating conditions. In addition, pilot training was often deficient in interpretation of weather conditions and in instrument flight procedures. They also found that modified EMS interiors and various program practices often compromised crashworthiness standards, resulting in an increased risk of injury and death.

The NTSB report ended with specific recommendations—some to the FAA and some to the American Society of Hospital-Based Emergency Air Medical Services (ASHBEAMS, which changed its name in 1989 to the Association of Air Medical Services). Included in these recommendations were: improved interior modifications that would not compromise crashworthiness; the use of shoulder harnesses and protective clothing (e.g., helmets, flame-resistant suits, protective footwear); the development of program safety committees; improved training in a number of areas, including marginal weather operations, emergency procedures, pilot-crewmember coordination, and communications.

In reviewing the NTSB data an interesting observation is made with regard to inclusion criteria and selection. A 1986 Chicago accident is included that did not

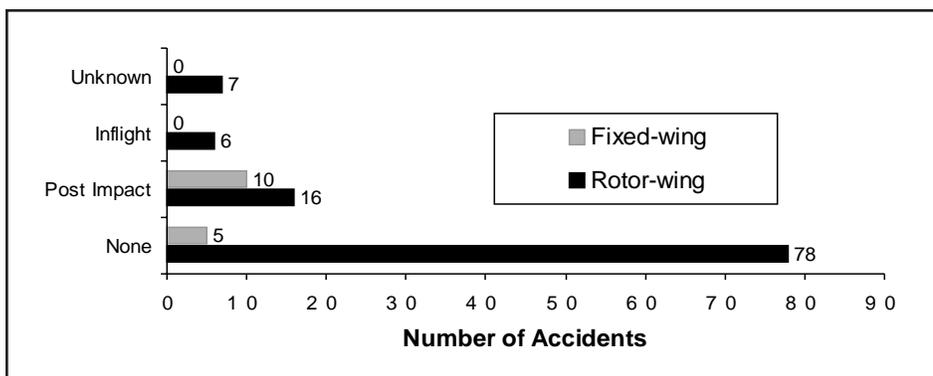


Figure 1–20: Air Medical Accidents with Fires Adapted from: Frazer, *AirMed*, Sept/Oct 1999

involve a medical helicopter, but a corporate helicopter that suffered a tail rotor strike upon departing a hospital helipad after dropping off a passenger. The NTSB, however, chose to include this as a medical helicopter accident even though, in this author's opinion, the helicopter did not meet the NTSB inclusion criteria (aircraft dedicated to the EMS mission, has trained medical personnel on board, and the pilot is employed primarily to fly dedicated EMS missions).

The NTSB report identifies a total of 88 accidents that occurred during their designated study period (1978 through 1986). Based upon their inclusion criteria, the study group was reduced to the 47 "mission" accidents. The "Industry Reported EMS Accidents" came from six different reporting sources and their respective databases: American Society of Hospital-Based Emergency Air Medical Services (ASHBEAMS, now AAMS), Aviation Safety Institute, Hospital Aviation Magazine, FAA Accident/Incident Data System, National Emergency Medical Services Pilots Association (NEMSPA), and the NTSB Accident database.

FLIGHT SAFETY FOUNDATION: HUMAN ERROR AS MAJOR CAUSE OF U.S. COMMERCIAL EMS HELICOPTER ACCIDENTS

Patrick Veillette, Ph.D., studied a total of 87 HEMS accidents and 56 incidents from January 1987 through December 2000. Of interest, Veillette's 2001 study and his database begin where the 1988 NTSB report concluded.

Much like Frazer's studies, this comprehensive report analyzes many common factors related to HEMS accidents, including phase of flight, weather-related accidents, collisions with obstacles, and mechanical-related accidents. Veillette, however, also presents his findings regarding human error as a major factor in HEMS accidents. His discussions also include the findings of numerous other safety reports, FAA Advisory Circulars, and publications.

Veillette concluded that human error was associated with 66 of the 87 (76%) HEMS accidents studied. Of the fatal accidents studied, human error was associated with 84% (27 of 32). Recurring human error factors identified and the number of accidents for which they were cited is shown in Figure 1-21.

Veillette also reviewed the effect human error had on the various phases of flight accidents. He found that human error accounted for 68% of the en route accidents, 91% of the accidents during approach and landing, and 82% of the accidents during takeoff. Of the approach and landing accidents, 41% were due to a collision with an obstacle,

while 50% of the takeoff accidents were collisions with obstacles. Figure 1-22 shows the most common phase of flight accident categories.

As mentioned, Frazer and Veillette have reviewed many of the same characteristics surrounding HEMS accidents. Although their findings are similar, several differences are noted. Since the NTSB database was the major source for both studies, the variations must take into account the different years each author included in their study and the fact that Frazer also included fixed-wing accidents. Veillette's review of 1987-2000 excluded many of the years with the highest number of HEMS acci-

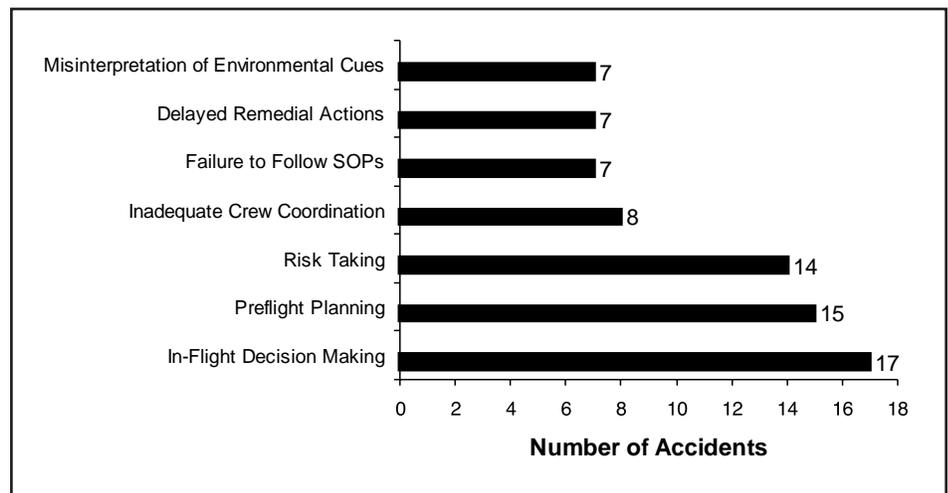


Figure 1-21: Human Error Factors in HEMS Accidents, 1987-2000

Adopted from: Veillette, *Flight Safety Digest*, April/May 2001

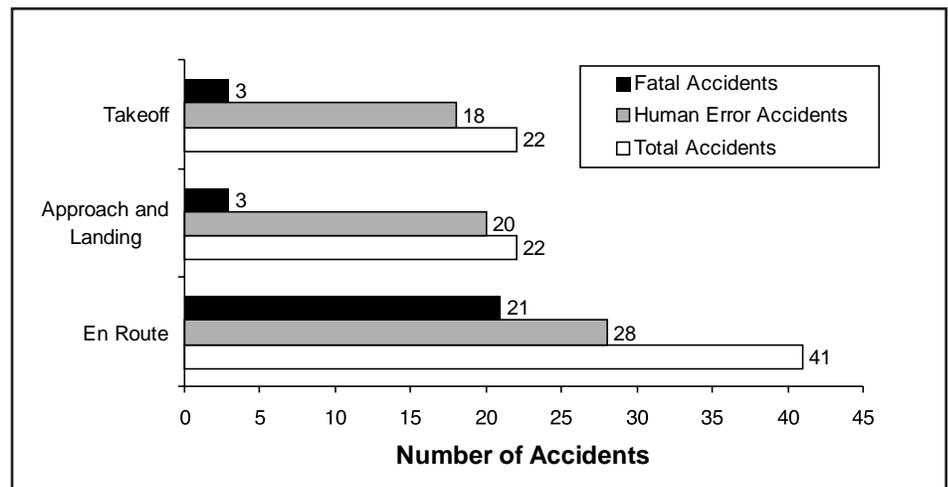


Figure 1-22: Phase of Flight Accidents, 1987-2000

Adopted from: Veillette, *Flight Safety Digest*, April/May 2001

dents (1982–1986) that were included in Frazer’s study. However, Veillette may have been able to identify any significant trends that may have changed *after* the high number of accidents of the early ’80s.

Frazer’s 2001 study found that 18% of the accidents were the result of collisions with obstacles, while Veillette’s report identified 31%. Another difference noted was with regard to aircraft damage and post-impact fires. In Frazer’s study of 122 aircraft accidents, 57% were destroyed and 42% had substantial damage. Veillette’s data is nearly reversed, with 41% destroyed and 59% sustaining substantial damage. Frazer also found that 15% of the helicopter accidents resulted in a post-impact fire, while Veillette study found less than 6% resulted in a fire.

Veillette identified 47% of accidents occurring en route compared to 36% in Frazer’s study. This difference, however, could be due to the number of categories identifying the various phases of flight. Veillette listed only 5 categories (takeoff, en route, maneuvering, approach and landing, ground), while Frazer listed 8 (takeoff, cruise/en route, maneuvering, approach, landing, hover, descent, climb). Finally, as previously noted, Veillette found 76% of the accidents to be associated with human error, while Frazer’s study found this to be 65%.

Veillette made several references to the crew in his analysis of the accident database. He found that inadequate crew coordination was cited in eight accidents. Each of these accidents involved a collision with obstacles that occurred during takeoff or landing. Other factors included incorrect or untimely information and distracting comments or movements by the medical crew during a critical phase of flight. He also cited four accidents and six incidents that were caused by cowlings and panels that separated from the helicopter. In half of these events, the medical crew had closed the cowlings improperly prior to flight.

Unique to this study, Veillette reports on his personal observations made during more than 400 HEMS transports between 1995 and 2000. His observations were categorized by the type of flight—scene response (128), interhospi-

tal transfer (58), and repositioning (247). It was not mentioned if these observation flights were all with the same program or with different programs. Veillette observed that during none of the transports was the medical crew wearing helmets, while the pilots wore helmets more than 70% of the time. The author did not mention whether helmets were available to the medical crew or to all of the pilots.

Most surprising was his observation regarding the use of seat belts and shoulder harnesses by the medical crew. In 100% of the repositioning flights, the medical crew was wearing seat belts during takeoff, but only 45% were wearing shoulder harnesses. However, on takeoff from scene responses, only 11% were observed to be wearing seat belts and only 4% had shoulder harnesses fastened. The percentage was even lower on takeoff from interhospital transfers, with seat belts buckled only 6% of the time and shoulder harnesses only 4%. While this would appear to be a serious breach of routine safety protocols, Veillette only comments that “because of their in-flight medical duties, medical crewmembers frequently are not seated in energy-absorbing seats with their seat belts and shoulder harnesses fastened.”

Veillette’s article concludes with a complete listing of the accidents and incidents included in his database. In this same issue of *Flight Safety Digest*, Veillette offers a second comprehensive study that specifically addresses EMS airplane accidents. This second article, which spans 1983–2000, may be the most complete analysis of fixed-wing air medical accidents available. Both of these articles provide excellent information and detailed insight into various aspects of air medical accidents.

EMERGENCY MEDICAL SERVICE HELICOPTERS INCIDENTS REPORTED TO THE AVIATION SAFETY REPORTING SYSTEM

All too often, helicopter accidents include pilot fatalities. Many of these

accidents do not provide investigators with adequate and complete information as to the chain of events that led to the accidents. With the high number of fatal HEMS accidents, information from alternative perspectives could be helpful to identify potential problems and prevent future accidents. One such perspective is reports of aviation incidents that did not result in accidents. The U.S. National Aeronautics and Space Administration (NASA) Aviation Safety Reporting System (ASRS) has the world’s largest database on aviation incidents and serves as an important resource for this alternative perspective.

The NASA-Ames Research Center searched the ASRS database for reports related to EMS helicopter incidents. From 1986 through 1991, 68 of 81 HEMS incident reports were considered relevant and were included in their study. These reports, which were voluntarily submitted by EMS helicopter pilots, air traffic controllers, and pilots of other aircraft, (i.e., anyone who observes an incident) often included the crucial “chain of events” and the successful resolutions of the incidents. The benefit of these reports was that they enabled the pilot to report what he/she was thinking at the time of the incident.

The objectives of the Ames study were to: (1) identify the types of safety-related incidents reported to ASRS in EMS helicopter operations; (2) describe the operational conditions surrounding these incidents, such as weather, airspace, flight phase, and time of day; and (3) assess the contribution to these incidents of selected human factors, such as communication, distraction, time pressure, workload, and flight/duty impact.

The type of information obtained from the ASRS incident reports and their narratives is very different from the type of accident data already presented. The data were evaluated according to incident variables, operational variables, and human factor variables.

Incident Variables

The Ames report found that non-adherence to the Federal Aviation Regulations (FARs) was identified in 53% of these reports. This included violations of flight/duty limitations, mainte-

nance requirements, and so on. Airspace violation ranked second (23%). Conflict or near-midair collision (NMAC) and in-flight encounter with instrument meteorological conditions (IMC) were reported in 14% of the reports. It should be noted that 22% of the reports identified problems that could not be specifically addressed by other incidents. Figure 1–23 lists the anomalies reported in the ASRS reports.

Operational Variables

This category includes phase of flight, weather conditions, time of day, and type of airspace involved at the time of the incident. Most commonly, HEMS incidents occurred during cruise and during good weather. The time of day most often involved was from 1201 to 1800 hours, which generally corresponds with the busiest time of day for flight programs. The reported incidents occurred in all types of controlled and uncontrolled airspace.

In comparing their findings with the 1988 NTSB report, the Ames report found several similarities and one significant difference. The Ames report

found that in comparing the two studies, the weather conditions (i.e., unplanned entry into IMC), airspace, phase of flight, and experience levels of the pilots were similar. In addition, the quality and interpretation of weather information was noted as a concern in both studies. In the Ames report, they found that pre-flight weather briefings had been obtained in 80% of the incidents, but 75% of the briefings did not match the actual weather conditions the pilots encountered in flight.

One difference noted between the NTSB and Ames report was IFR currency. In the ASRS study, 68% of the HEMS pilots had an instrument rating and 66% were IFR current at the time of the incident. In contrast, in the NTSB report 86% of the pilots were IFR-rated, while only 6% were IFR current. The Ames report concluded that “this finding appears to be a compelling reason to advocate IFR currency for EMS pilots, although additional research is necessary to reach this conclusion because of the limitations of the ASRS data.” The narratives in these ASRS incidents reported that IFR rating and currency were very helpful, if not invaluable.

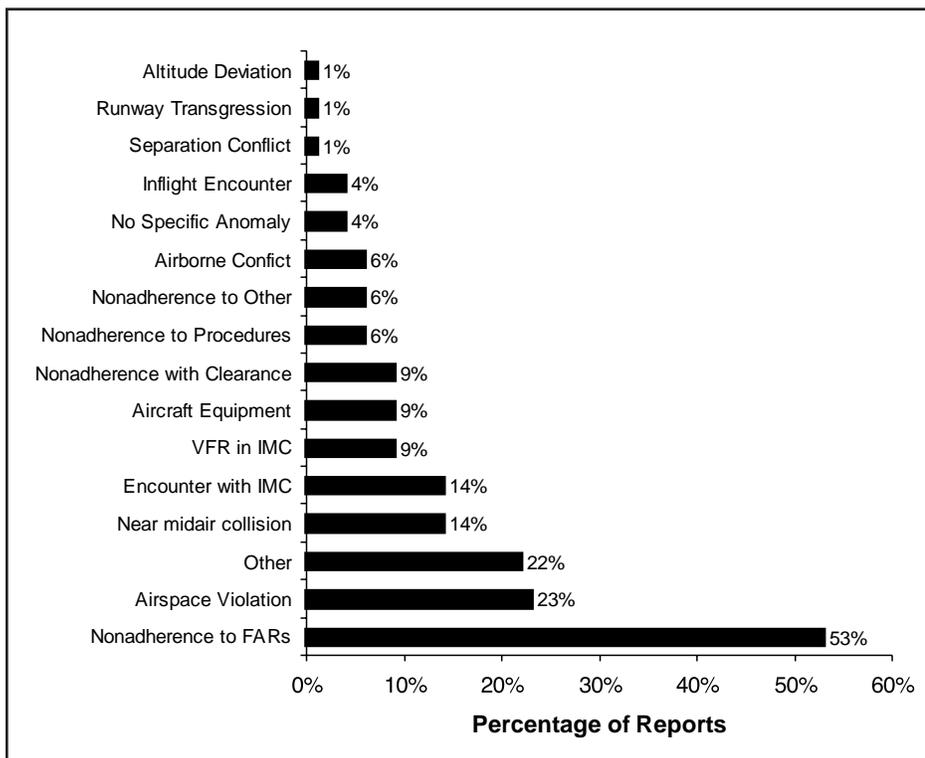


Figure 1–23: Frequency of ASRS Reported Anomalies HEMS, 1986–1991 (n=68)
Adapted from: Connell, Flight Safety Foundation, 1995.

Background Information: Instrument Rating, Currency, and Proficiency

Rating: The FAA defines “rating” as “a statement that, as a part of a (pilot’s) certificate, sets forth special conditions, privileges, or limitations.” To achieve an instrument rating, a pilot must pass a written test and a flight test given by the FAA. Upon passing these tests, the instrument rating becomes part of the pilot’s certificate (license) and the pilot is now legal to fly under instrument conditions for the next six months.

Currency: To maintain currency, a pilot must have flown, within the preceding six months, at least six (6) instrument approaches in a helicopter, completed holding procedures, and intercepted and tracked courses through the use of navigation systems. The flight experience must be repeated at least every six months to maintain IFR currency.

It is important to note that an IFR flight must be to a location (e.g., an airport or helipad) that has an authorized instrument approach. IFR flight *does not* facilitate travel to the scene of an accident or to most hospitals. Recent technology, however, has enabled dozens of hospitals to develop these instrument approaches.

Proficiency: If a pilot does not meet the instrument experience outlined in “currency” within the prescribed time (i.e., the preceding six months) or within 6 calendar months after the prescribed time, he/she will not be able to fly under IFR conditions until he/she passes an instrument proficiency check. This must be in an appropriate aircraft (i.e., for helicopter pilots, it must be in a helicopter) and must be given by an examiner, a company check pilot, an authorized flight instructor, or an individual authorized by the FAA to conduct instrument practical tests. Once the pilot has passed this check he/she may fly under instrument conditions for the next 6 months.

Human Factor Variables

Concerns related to communications, time pressure, and distractions were reported at very high rates as seen in Figure 1–24. In addition, workload and flight/duty conditions were also identified in the ASRS reports.

Communications

Of the communications incidents, 60% involved pilot-air traffic control (ATC) communications. Another 13% were communications problems between pilots and weather services (i.e., poor or inaccurate weather information that became a major contributor to in-flight encounters with IMC). Communication difficulties between pilots, HEMS dispatchers and ground personnel (e.g., police, firefighters, paramedics, ground crew, maintenance) were also reported as a frequent problem, especially if they interfered with ATC communications.

Time Pressure

Time-related pressures were cited as a frequent contributor to the ASRS incidents. These pressures centered around four different considerations: patient condition, rapid mission preparation, flight to the patient pick-up location, and low fuel. Patient condition was reported 44% of the time and was the most important contribution to time pressure. The critical condition of a patient could create a sense of maximum urgency. As a result, preflight planning may be inaccurate or preflight inspections and checklist may be hurried and incomplete. Other reports cited such oversights as not stopping for refueling; failure to obtain or review correct charts; overflying scheduled aircraft maintenance; inadequate or less-than-thorough weather briefings; and inade-

quate evaluation of weather briefings preceding the go/no-go decision. The Ames report found that time pressure associated with the patient's condition seemed to be present regardless of whether the patient was already onboard the aircraft or the pilot was en route to patient pick-up.

Most programs strive to isolate the pilot from knowing any medical information so that their flight decisions are made objectively. Unfortunately, we may not be as successful as we would hope. HEMS pilots are well aware that their services are generally requested when there is a critically ill or injured person in need of transport. In addition, the pilot may be faced with a sense of urgency from both verbal and/or nonverbal signals from the medical crew. One ASRS report stated, "No flight is so important that the lives of the flight crew should be jeopardized due to incomplete or inaccurate preflight planning."

Distractions

Distraction from the primary task of flying the aircraft was reported in many of the ASRS incidents. External factors created many distractions that were cited in the reports. These included in-flight aircraft equipment problems, the need to monitor multiple radio frequencies, traffic avoidance in high-density traffic areas, interruptions, radio frequency congestion, poor visibility due to haze or night operations, marginal weather, noise from on-board medical equipment, and impending low-fuel situations. Many of these distractions could also lead to time-pressure situations.

Internal factors were also reported which led to significant distraction. This included personal or family-related concerns, anxiety in the current situation, disorientation, involvement in patient

condition, confusion about procedure, and general inattention.

Distractions can lead to accidents. In our daily activities, it is common to try to do multiple things at the same time—to multitask. While driving, it seems to make perfect sense to get something else done. Many people use their handheld cellular telephones. There are several recent studies that indicate a strong correlation between the use of cell phones and the increased probability of an auto accident due to the distraction.

Aviation is no different. The idea of the sterile cockpit began in commercial airlines and has been around for years. By eliminating unnecessary talking during critical stages of flight, we can reduce distractions and improve our safety record significantly. Medical crewmembers, patients, passengers, and even other pilots, despite good intentions, can be significant distracters.

Workload and Flight/Duty Considerations

While workload (12%) and flight/duty considerations (4%) were reported in the ASRS incidents, the Ames study concluded that they were not a significant contributor to any HEMS incident.

However, workload, flight/duty length, crew rest, and the number of duty days can influence many factors, including judgment, error recognition, concentration, forgetting tasks, fatigue, and ultimately can lead to aviation incidents.

An unexpected finding in the HEMS ASRS reports was that cruise flight was a common time for HEMS safety incidents. Airspace violations and near-midair collision most frequently occurred in cruise flight and in VFR weather. In-flight weather encounters were also reported as occurring most often in cruise flight. During cruise, it would be anticipated that cockpit activity would be low—unlike takeoff and landing. However, it appears that the HEMS pilot might be attending to tasks inside the cockpit, rather than watching for conflicting traffic, low clouds, or airspace boundaries. These cockpit activities might include providing position reports to dispatch, coordinating with the medical center, programming nav aids, or communicating with other EMS personnel.

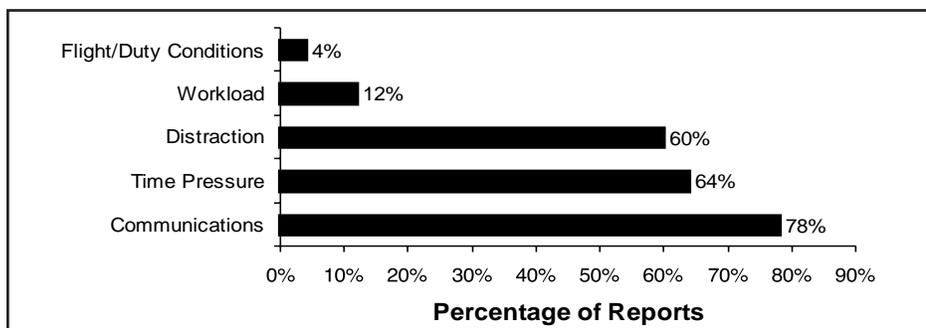


Figure 1–24: Human Factors in HEMS Incident Reports (n=68)
Adapted from: Connell, Flight Safety Foundation, 1995.

The Ames report focused on the unique demands placed on the HEMS pilot that led to distraction and time pressure. It concluded that these demands could compromise good communications, thorough planning, cooperative teamwork, and safe flight during patient transport. It recommends that steps need to be taken to improve communication, decrease distraction, decrease time pressure to realistic levels, and assist in workload management.

Ames proposed that Crew Resource Management (CRM) was not just for major airlines or big companies. Effective communications among all HEMS team members—pilots, flight nurses, paramedics, doctors, administrators, and communication specialists—are vital if the HEMS team is to perform its duties efficiently, successfully, and safely. CRM will be discussed in more detail in Section 4 of this report.

AIR MEDICAL ACCIDENT ANALYSIS

In April 2000, an Air Medical Safety Summit was convened to address the rising number of air medical accidents. From this Summit of industry leaders and safety experts came the Air Medical Safety Advisory Council (AMSAC), the Air Medical Service Accident Analysis Team and several other initiatives.

The Air Medical Service Accident Analysis Team was created to study past accidents, analyze the root causes of these accidents, and identify effective and feasible interventions that would prevent future HEMS accidents. Chaired by Richard Wright, Jr., of the Helicopter Association International, the main focus of the Team was human factor accidents. It was felt that identified interventions in this area might have the greatest impact on accident prevention and safety.

The Team identified 20 HEMS accidents between November 1993 and November 1999 whose Final NTSB Accident Reports included extensive data for review and evaluation. The process used to examine these accidents is referred to as “root cause analysis.”

Event Sequence

A timeline of events was developed for each flight from the available accident report. This included all aspects of the transport, from prior to the flight, during the flight, and ending with the accident itself.

Problem Statements

Any and all “problems” that could have contributed to the accident were then identified. Among the 20 flights, a total of 56 individual problems were identified. They were then classified as: pilot performance issues (23), aircraft issues (9), infrastructure issues (9), environmental issues (6), landing zone issues (5), and corporate and/or program management issues (4), as identified in Figure 1–25.

Intervention Strategies and Ratings

Interventions were next identified for each problem to determine what might have prevented the problem, potentially averting the accident. A total of 65 unique interventions were proposed, which were categorized as Training Interventions, Equipment Interventions, Air Traffic Management Interventions, Regulatory or FAA-sponsored Interventions, National Airspace (NAS) or Infrastructure Interventions, or Miscellaneous Interventions.

Each intervention was evaluated and scored by the Team for its effectiveness, yielding a ranking, or *Effectiveness Score*. The combined score was then divided into thirds to group the interventions that rated *High* (21–17), *Moderate* (16–13) and *Low* (12–8) *Effectiveness*.

The next step was to evaluate and score each Intervention to determine its technical feasibility, financial feasibility, regulatory feasibility, and operational feasibility. A range from 48 to 13 was obtained for the 65 interventions. As before, the combined scores were then divided into thirds, to rank the interventions as *High* (48–37), *Moderate* (36–32), and *Low* (31–13) *Feasibility*.

Recommendations

The results were combined into a matrix, with interventions classified into nine different categories. It was the Team’s recommendation that AMSAC focus efforts within the air medical industry to develop implementation strategies for those interventions that ranked highly effective and highly feasible. Recommended for consideration were those interventions that were identified as highly effective but moderately feasible, highly feasible but moderately effective, and those that were moderately effective and moderately feasible. Interventions classified as low effectiveness and/or low feasibility were not recommended by the Team for implementation or further pursuit. Figure 1–26 lists the nine categories and the Team’s recommendations to AMSAC.

This document is an excellent resource that takes a detailed and comprehensive look into the specific problems and events that have led to previous HEMS accidents. The Team has also provided a comprehensive list of specific technologies, training, regulations, and operational enhancements and rankings of their effectiveness and feasibility as interventions that can improve the safety of air medical transport and reduce the number of accidents. However, in making their recommendations, the Team divided the scores into thirds to yield their *High*, *Moderate*, and *Low* ratings. In doing so, it is inevitable that some interventions will miss a cut-off by a mere point or two. For example, full motion simulators, improve safety programs and improve safety cultures were each classified as “*High Effectiveness*” but fell one point short of *Moderate Feasibility*. Following the specific recommendations of the Team, these highly effective interventions would not be pursued. Clearly, the most highly ranked interventions in both effectiveness and feasibility should be investigated very carefully for possible implementation. However, operators, manufacturers, associations, and programs should review this entire list of possible interventions to identify opportunities, such as full-motion simulators, that are within their capacity for improvement and enhanced safety.

AIR MEDICAL ACCIDENT ANALYSIS: CONSOLIDATED PROBLEM STATEMENTS

<p>Pilot Performance Issues:</p> <ul style="list-style-type: none">• Loss of situational awareness• Poor aeronautical decision making• Limited experience in make/model• Flight check not conducted in operational type of aircraft• Pilot disregarded company policies• Inadequate preflight planning• Pilot failed to obtain weather briefing• Pilot ignored weather briefing• Pilot not wearing helmet• Pilot continued VFR flight into IMC conditions• Pilot descending to avoid IMC• Pilot fails to maintain safe altitude• Pilot fails to conduct area recon• Pilot fails to conduct pre-departure briefing• Improper response to inflight emergency• Inadequate Nr (rotor RPM) control• Pilot failed to recognize and avoid power settling• Improper pilot technique• Pilot took off with sun in eyes• Destination position not entered in navigation equipment• Pilot failed to use aircraft searchlight to detect wires• Pilot failed to hear or respond to ATC special VFR clearance• Pilot's attention is diverted to inside the cockpit <p>Environmental Issues:</p> <ul style="list-style-type: none">• Night VFR operations• Night IMC operations• Reduced visibility• Mountain operations• High altitude operations• Featureless terrain	<p>Aircraft Issues:</p> <ul style="list-style-type: none">• Aircraft not IFR certificated• No autopilot or second pilot• Poor configuration of navigation equipment• Pilot unable to determine altitude above LZ• Pilot unable to detect weather• Pilot unable to detect wires• Misleading/inaccurate fuel quantity gauge• Aircraft flotation inadequate for existing sea conditions• Uncrashworthy fuel tank <p>Infrastructure Issues:</p> <ul style="list-style-type: none">• ATC unclear regarding pilot's request• Inadequate vector by ATC to intercept localizer• Pilot unable to obtain ATIS (Automated Terminal Information Service) information• Airport uncontrolled• Airport congested, requiring landing on ramp• Helipad small• Helipad surrounded by obstacles• Powerlines did not meet marking criteria• Powerlines not depicted on aeronautical charts <p>Landing Zone Issues:</p> <ul style="list-style-type: none">• Difficulty identifying landing zone• No landing site supervisor• Incorrect/inadequate obstacle information on LZ• Congested landing zone• Obstacle-rich environment <p>Corporate/Management Issues:</p> <ul style="list-style-type: none">• Corporate pressure to complete the mission• Personal pressure to complete the mission• "Ready Aircraft" change required equipment transfer• Preflight preparations rushed
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Figure 1–25: Consolidated Problem Statements

Adopted from: *Air Medical Accident Analysis*, 2001

		EFFECTIVENESS		
		High	Moderate	Low
FEASIBILITY	High	<ul style="list-style-type: none"> • Enhance the training for night flying operations • Enhance the training for mountain flying operations • Equip aircraft with Terrain Avoidance Warning Systems (TAWS) • Equip aircraft with radar altimeters • Provide aircraft with mission-essential equipment • Improve the content of weather briefings 	<ul style="list-style-type: none"> • Enhance the awareness of accident causes • Improve physiological training • Improve training with avionics equipment: usage, capabilities, etc. • Improve weather radar • Encourage greater utilization, interaction with and assistance from Air Traffic Management • Improve/enhance training of ATC personnel in rotorcraft operations and capabilities • FAA to enhance training elements of Biennial Flight Reviews and Pilot Training Standards 	<ul style="list-style-type: none"> • Readily available crew/passenger briefing cards • Fuel flow indicators • Simplify calling FSS • Publish a mountain flying advisory circular • Publish a “flat light/whiteout” advisory circular • Require flight plans • Provide more UNICOM frequencies
	Moderate	<ul style="list-style-type: none"> • Conduct/enhance annual IFR proficiency checks • Conduct/enhance training to improve the understanding of weather briefings • Enhance overall training: recurrent, professional knowledge, etc. • Conduct/enhance training in ADM • Establish an integrated and structured Pilot Training Program • Conduct/enhance mission-oriented training • Conduct/enhance CRM training • Equip aircraft with Moving Map Displays to provide weather, obstacle, and terrain data • Equip aircraft with avionics to provide a vertical awareness display or warning • Standardize cockpits of similar make/model used in similar operations • FAA to enhance/improve contents of annual IFR proficiency checks • Establish national criteria for the marking of wires and towers 	<ul style="list-style-type: none"> • Operators to enhance training for Biennial Flight Reviews and Pilot Training Standards • Develop helicopter-specific, mission-specific computer-based emergency procedures simulators • Develop satellite-based Communications, Navigation and Surveillance (C/N/S) technology • Increase the rate of commissioning of new AWOS/ASOS (Automated Weather Observing System/Automated Surface Observing System) facilities • Improve aeronautical charts (symbolology, data, etc.) 	<ul style="list-style-type: none"> • Improve pilot handbooks • Data link technology • Require annual calibration of fuel quantity gauges
	Low	<ul style="list-style-type: none"> • Horizontal Awareness From Terrain • Synthetic vision • Heads-up display • Night vision devices • Full-motion simulators • Enhance visibility/detection of wires and towers • Change corporate mind-set • Improve safety culture • Improve safety program 	<ul style="list-style-type: none"> • ADS-B (Automatic Dependant Surveillance-Broadcast) Technology • Automated voice call-outs • Over-bank warnings • Excess terrain closure warnings • improve equipment with state-of-the-art technology • Prohibit night flying by non-IFR rated pilots • Require human factors/ergonomics in cockpit designs 	<ul style="list-style-type: none"> • Increase dual-pilot time prior to solo PIC • Increase time requirements for “mission certification” • Obstacle database • Enhanced ice detection equipment • Raise minimums for night instrument approaches • Require ATC monitoring of instrument approaches • Prohibit night VFR • Update FAR Part 135 requirements • Require crashworthy fuel tanks for certification

Adopted from: Air Medical Accident Analysis, 2001

HEMS ACCIDENTS AND INCIDENTS, 1998 TO 2001

The past four years has seen an alarming increase in the number of HEMS accidents across the nation. No one is certain why there have been 43 accidents (plus one dual-purpose medical helicopter accident) in four years. From 1987–1997, dedicated HEMS has averaged 4.9 accidents per year. The past four years averaged 10.75 per year. Not since the four year period of 1983 to 1986 have we seen such a large number of accidents.

While a few of the reports that we reviewed included accidents from 1998 to 2000, none of these studies isolated these years from the rest of their accidents. Therefore, with no published review of the most recent series of accidents, we determined that it was necessary to do our own preliminary review of these accidents to see if any trends could be identified.

Several resources and databases were reviewed in the development of Attachment 1. This table presents the pertinent data on 44 HEMS accidents between 1998 and September 30, 2002.

Attachment 1 does not include any fixed-wing EMS. In addition, we have not included an accident that killed three crewmembers in England, a non-EMS helicopter that crashed on a hospital helipad, or an “as needed” service that crashed after picking up three firemen to respond to a medical emergency in Hawaii. Finally, two additional accidents were not included which involved medical helicopters that had been “out-of-service” for at least several days and were undergoing post-maintenance test flights.

Of the 44 accidents from 1998 to 2001, 15 (34%) resulted in at least one fatality. For the 1980s, our accident database showed 39% of all accidents resulted in at least one fatal injury. From 1990–1997 the rate increased to 47%. Despite the increase in accidents over the past four years, the percentage of fatal accidents has declined by nearly 30%. Figure 1–27 depicts the percentage of fatal accidents since 1980. As the figure shows, the last four years has had the lowest consecutive 4-year fatality rate in HEMS history since the early 1980s.

Looking at the breakdown of all injuries (Figure 1–28), there is also a significant difference noted in the percentage of

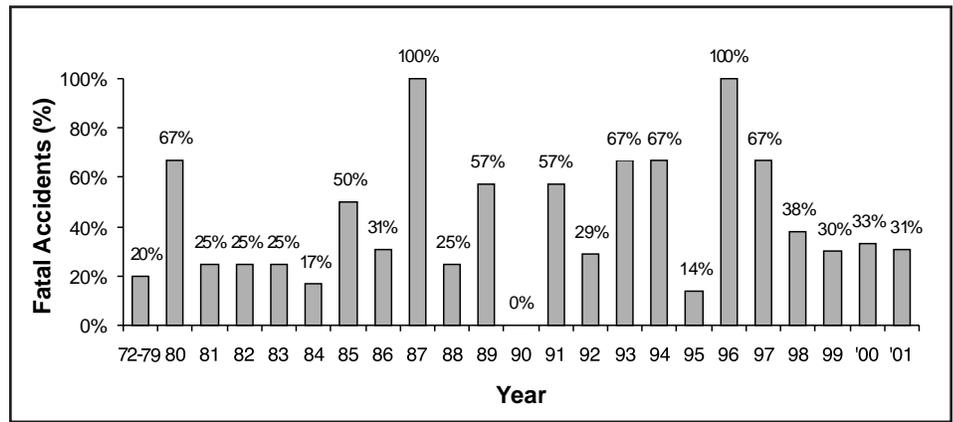


Figure 1–27: Percentage of Fatal Accidents per Year

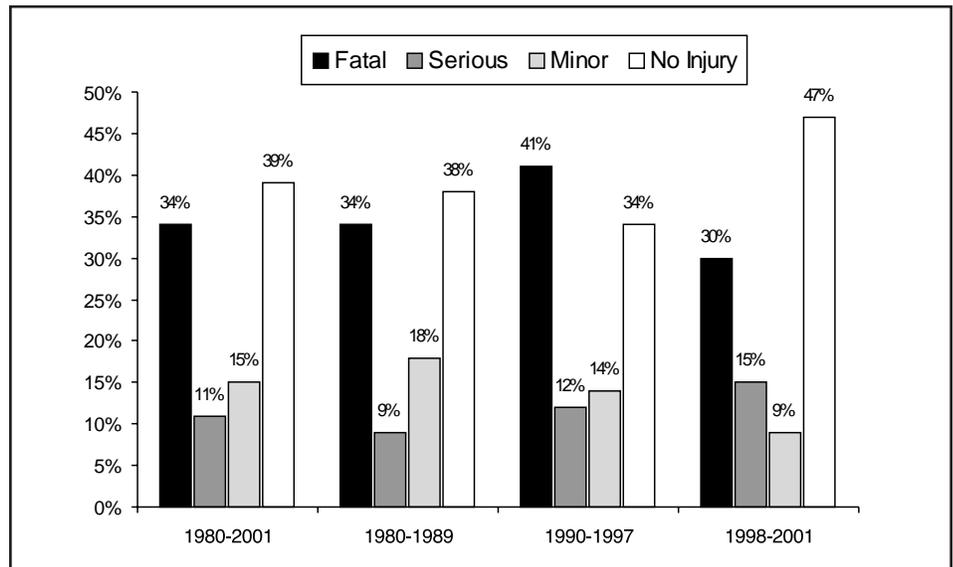


Figure 1–28: Severity of Injuries for HEMS Accidents, 1980 – 2001 (1980–2001, n=494; 1980–1989, n=247; 1990–1997, n=116; 1998–2001, n=131)

crewmembers who sustained no injuries in HEMS accidents. Figure 1–28 shows four different comparisons: the entire 21-year study period; the 1980s; 1990–1997; and finally 1998–2001. The percentage of fatal injuries has decreased in 1998–2001 and we now see 47% of the crewmembers and passengers sustained no injuries.

Since 1998, a slightly higher percentage of HEMS accidents occurred at night (52%). More accidents occur during the cruise phase of flight (16) than any other phase and we now see a similar number of accidents occur on takeoff and landing (8 each). More accidents (45%) are taking place during scene missions than previously noted (35%). Finally, our preliminary review of the HEMS accidents seems to show a decrease in the percentage of weather-related accidents. Frazer had

noted an increase in weather-related accidents from 22% in the '80s to 32% in the early and mid-'90s. From 1998 to 2001, there appear to be 6 weather-related accidents, dropping the percentage to 14%.

HEMS ACCIDENT AND FATAL ACCIDENT RATES

The UCAN Safety Committee felt that an important aspect of our research would be to determine HEMS accident and fatal accident rates for our entire study period (1980–2001). In order to normalize the raw accident data for a meaningful comparison of dedicated HEMS accidents, it is necessary to have two key elements—the number of accidents (total and fatal) and the number of flight hours flown or the number of patients transported for the

entire industry each year. We have already reviewed the accident data that is readily available from several sources. Unfortunately, as previously mentioned, a major obstacle is our lack of accurate HEMS exposure data (e.g., flight hours, patients transported) making it impossible for a meaningful year-to-year comparison. Dual-purpose medical helicopter accidents are not included in this portion of the report.

Methodology

Our research model required that an extensive review of the air medical literature be conducted to determine what data was available that could be used to normalize the HEMS information. We found that in 1982, *Hospital Aviation* began to track and publish statistics and accident rates that were based on the number of patient transports (rather than flight hours) for the air medical industry. In 1988, *Hospital Aviation* also looked at revenue flight hours as well as patient transports. Their survey found that the average patient transport corresponded to 1.05 revenue flight hours. Because of this finding, accident rates continued to be tracked based upon patient transports. No data were collected on total hours flown (training, repositioning, maintenance, PRs, etc.). In the journals, the “per 100,000 patients transported” accident rates were found through 1992 and resurfaced again in a 1997 article that provided a graph for the years 1978 through 1995.

“Annual Transport Statistics,” the results of another industry-wide survey, was published first in *Hospital Aviation*, and then in the *Journal of Air Medical Transport*, the *Air Medical Journal*; and then in *AirMed*. This analysis provides information on averages per flight program (as well as highs and lows) for the year, region-by-region, and across the United States. This included information on the average number of patients transported, interfacility missions, scene missions, night flights, and loaded miles. In 1994, they also started to include average flight hours in the survey results. Personal correspondence with Bill Rau, who had authored the transport survey articles since 1996, stated that the survey asked for “total annual flight hours

excluding PR flights.”

A final source of HEMS statistics was the “Mid-Year Report” that identified (among other related data) the number of hospital-based programs and helicopters. This data was found from 1984 through 1989 in *Hospital Aviation* and subsequently in the *Journal of Air Medical Transport*. Several additional articles and the 1988 NTSB report were also reviewed to provide raw data.

Total flight hours and total patient transports were unavailable for more than 50% of the years reviewed. From the “Annual Transport Statistics” we did have the average number of patients transported per program per year and the average flight hours per program. Unfortunately, we lacked any estimate as to the number of HEMS programs in operation since 1992. In order to normalize the HEMS data, the missing information would need to be obtained or estimated.

In an effort to estimate the number of HEMS programs, several assumptions were made. If we could determine the number of programs and helicopters currently in operation (November/December 2000), we could estimate the total flight hours and patients transported during the year. In addition, unlike the early 1980s, we assume that the growth in the industry has been fairly constant over the past eight years. We would then be able to estimate the number of programs and helicopters for the years lacking data.

To determine a fairly accurate number of dedicated HEMS programs and helicopters, we undertook a review of the Association of Air Medical Services (AAMS) Membership Directory and the Directory of Air Medical Programs, published in the May/June issue of *AirMed*. Unfortunately, neither resource is complete. Not all air medical programs are AAMS members and neither directory includes the total number of aircraft. To supplement this data, a survey was posted on the Internet’s *Flightweb* listserv. The survey requested state-by-state information on the number of dedicated HEMS programs (hospital-based, independent, etc.) and the number of dedicated helicopters.

Knowing the flight hours is the next consideration in an attempt to normalize

the HEMS data. The NTSB document reported flight hours for 1980 through 1985, but did not specify if their figures correspond to revenue flight hours or total flight hours. In addition, the *AirMed* surveys provide average flight hours per program from 1993 to 2000. If we are successful in estimating the total number of HEMS programs in operation from 1993 to 2000, we will be able to estimate the total flight hours.

Total flight hours is an important consideration in our evaluation. In HEMS, a considerable number of accidents occurred on non-patient missions—including PRs, refueling, maintenance, training, and so on. The average flight hours per program, as published in the *AirMed* surveys, should have included all flight hours except PRs. The vast majority of HEMS flight hours are patient missions. Personal correspondence with several HEMS programs and operators suggests that non-patient flight time may range from 5 to 15%. PR flights made up approximately half of this for many programs.

In an effort to more accurately determine the average number of total flight hours per program, a survey of five of the largest HEMS operators was conducted. These operators were chosen with the knowledge that they account for the majority of the air medical programs in the country. The operators were asked for total flight time, total number of programs and total number of helicopters they operated for the years 1998 through 2000. The goal was to compare these flight hours with the information published in *AirMed* for 1998 and 1999. In addition, a correlation could then be made comparing revenue flight hours and total flight hours for other years.

Results

In review of the available published statistics, several limitations and problems were identified that make accurate yearly comparisons very difficult. Most important, the “Annual Transport Statistics” report only on hospital-based HEMS programs. Over the years, more and more HEMS operations have deviated from this original, yet still dominant, model. In 1989, the journals began sending surveys to non-hospital helicopter

programs, but the data was never included in the published average statistics. In 1989, the total number of patients transported by these non-hospital programs was referenced. However, these numbers included some dual-purpose helicopter programs as well.

Another problem was timing of the data collected. Some statistics regarding the number of helicopter programs and total number of helicopters were published in *Hospital Aviation* in a mid-year (July) report, while other program and

helicopter statistics were based on the calendar year. The *Annual Transport Survey* was based on the calendar year until 1993 when it was switched to the academic (July to June) year for annual statistics tabulation. In general, annual accident statistics were based on the calendar year.

Since 1986 the journal surveys were sent to both helicopter and fixed-wing programs. The percentage of surveys returned ranged from a high of 96% to a low of 33%. In general, the yearly data

was fairly consistent. The one exception was 1994, which had significantly *higher* average flight hours per program and much *lower* loaded miles than other years.

The results of the literature search and the following calculations can be found in Figure 1–29. The data obtained from the various publications is presented in **bold italics** while the calculations and surveyed data is in plain type.

Helicopter EMS Programs and Helicopters. Data was available for the number of HEMS programs from 1972 to

Figure 1–29: HEMS Program, Helicopter and Accident Statistics (Published data is in bold italics)

1	Data for Year	72–79	1980	1981	1982	1983	1984	1985	1986	1987	1988	
2	Year Data was Published					[1984]	[1985]	[1986]	[1987]	[1988]	[1989]	
3	Avg Pts Flown / Program		546	676	654	553	570	590	623	698	697	
4	Avg Loaded Miles					61	63	61	61	61	58	
5	Avg Hrs Flown / Program	See total hours below (Line 8a)								654	733	732
6	Avg Flt Hr / Pt Transport								1.05	1.05	1.05	
7	Avg Total Hrs/Prog								710	795	794	
8a	Total Flight Hrs (-PR)		20,750	28,071	36,794	45,233	56,516	71,831	84,385	106,271	113,437	
8b	Total Flight Hrs		20,750	28,071	36,794	45,233	56,516	71,831	91,558	115,303	123,079	
9	# of Programs		32	37	49	62	76	101	129	145	155	
10	# of Helicopters		39	45	62	75	91	119	151	184	195	
11	Total Pts Flown	30,168	17,483	25,013	32,027	41,097	51,855	68,694	87,299	105,000	120,900	

14	Year	72–79	1980	1981	1982	1983	1984	1985	1986	1987	1988
15	HEMS Accidents	5	3	4	8	8	6	12	13	4	8
16	Dual-Purp. Acc.										
17a	Accident Rate (TFH)		14.46	14.25	21.74	17.69	10.62	16.71	14.20	3.47	6.50
17b	Accident Rate (-PR)		14.46	14.25	21.74	17.69	10.62	16.71	15.41	3.76	7.05
17c	Difference		0.00	0.00	0.00	0.00	0.00	0.00	1.21	0.29	0.55

18a	% programs w/ accidents		9.4%	10.8%	16.3%	12.9%	7.9%	11.9%	10.1%	2.8%	5.2%
18b	% helicopters w/ acc.		7.7%	8.9%	12.9%	10.7%	6.6%	10.1%	8.6%	2.2%	4.1%

19	Fatal Accidents.	1	2	1	2	2	1	6	4	4	2
20	Fatal Dual-Purp.										
21	Fatal Acc Rate		9.64	3.56	5.44	4.42	1.77	8.35	4.74	3.76	1.76
22	% Fatal Acc.	0.20	0.67	0.25	0.25	0.25	0.17	0.50	0.31	1.00	0.25
23	per 100,000 pts	16.57	17.16	15.99	24.98	19.47	11.57	17.47	14.89	3.81	6.62

Key to Lines:

2. Survey results are routinely published in the following year.
3. 83–99, published data. 80–82, calculated (total pts flown / # of programs)
4. 83–99, published data.
5. 93–99, published data. 86–92, calculated (ave # pts transported per program X 1.05).
6. 88, published data. 93–99, calculated (ave hrs per program / ave pts flown per program)
7. 98–2000, operator survey. 86–97, calculated (line 5 X 1.085)

1992 (Figure 1–29, Line 9) and information on the total number of helicopters was available for 1981 to 1991 (Figure 1–29, Line 10). From the *Flightweb* survey and personal follow-up, information was obtained from 45 of the 50 states (plus the District of Columbia). Program data for the remaining states was estimated from the *AirMed* directory. The survey results identified 231 dedicated HEMS programs, operating a total of 377 helicopters (not including back-up aircraft).

Additional follow up with several industry leaders and aircraft manufactur-

ers suggests that, if anything, these numbers may be slightly underestimated. From a telephone survey of the five aircraft manufacturers, it was estimated that there were a total of 462 dedicated and backup medical helicopters in the United States. This did not include dual-purpose helicopters. From the operators' survey, there was an average of one backup helicopter for every 7.1 dedicated helicopter in their combined fleets. Using this ratio, it would appear that our state-by-state survey of 377 helicopters would have an estimated 53 backup aircraft yielding a

total of 430 helicopters. This represents a variation of approximately 7% fewer aircraft compared to the number of helicopters from the manufacturers' survey. This may also indicate a slight discrepancy in the number of HEMS programs resulting from our Internet survey. In using the lower state-by-state survey results of 377 dedicated helicopters and 231 programs for our calculations, we realize that we may be underestimating our flight hours and number of patients transported. This also results in higher accident and fatality rates.

1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
[1990]	[1991]	[1992]	[1993]	[1994]	[1995]	[1996]	[1997]	[1998]	[1999]	[2000]	N/A	N/A
705	709	869	876	805	812	813	845	827	796	880	832	882
60	58	57	55	49	33	47	47	47	55	58	50.76	51
740	744	912	920	876	1159	785	823	823	814	821	813.22	911
1.05	1.05	1.05	1.05	1.09	1.43	0.97	0.97	1.00	1.02	0.93	0.98	
803	808	990	998	950	1258	852	893	893	854	921	841	957
122,141	129,534	162,416	169,141	166,245	226,778	158,221	170,727	175,573	178,447	184,839	187,854	210,396
132,523	140,545	176,221	183,518	180,376	246,054	171,670	185,239	190,497	187,216	207,327	194,271	217,584
165	174	178	184	190	196	202	207	213	219	225	231	231
213	231	225	242	259	276	293	309	326	343	360	377	400
125,200	159,027	154,682	161,087	152,771	158,881	163,865	175,291	176,427	174,501	198,098	192,238	203,772

1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
7	1	7	7	3	6	7	1	3	8	10	12	13
2		1							1			
5.28	0.71	3.97	3.81	1.66	2.44	4.08	0.54	1.57	4.27	4.82	6.18	5.97
5.73	0.77	4.31	4.14	1.80	2.65	4.42	0.59	1.71	4.48	5.41	6.39	6.18
0.45	0.06	0.34	0.32	0.14	0.21	0.35	0.05	0.13	0.21	0.59	0.21	0.20

4.2%	0.6%	3.9%	3.8%	1.6%	3.1%	3.5%	0.5%	1.4%	3.6%	4.4%	5.2%	5.6%
3.3%	0.4%	3.1%	2.9%	1.2%	2.2%	2.4%	0.3%	0.9%	2.3%	2.8%	3.2%	3.3%

4	0	4	2	2	4	1	1	2	3	3	4	4
1		1							1			
3.27	0.00	2.46	1.18	1.20	1.76	0.63	0.59	1.14	1.68	1.62	2.13	1.90
0.57	0.00	0.57	0.29	0.67	0.67	0.14	1.00	0.67	0.38	0.30	0.33	0.31
5.59	0.63	4.53	4.35	1.96	3.78	4.27	0.57	1.70	4.58	5.05	6.24	6.38

8a. 72–85, published data. 86–92, 93–99 calculated (# of program X Avg flight hrs per program).
 8b. 72–85, published data. 86–2000, calculated (line 7 X line 9)
 9. 72–92, published data. 2000, *Flightweb* survey. 93–99, calculated assuming consistent growth for 92–00
 10. 81–91, published data. 2000, *Flightweb* survey. 92–99, calculated assuming consistent growth for 91–00.
 11. 80–90, published data. 91–99 calculated (# of programs X Avg # of pts transported each year).
 17a. 80–99, calculated. (100000 X number of accidents)/total flight hours for the year
 17b. 80–99, calculated. (100000 X number of accidents)/total flight hours for the year, excluding PR

Our *Flightweb* survey results were entered into an Excel spreadsheet for the year 2000 along with the published data through 1991/1992. The estimated number of programs and helicopters for 1992/1993 through 1999 were then calculated assuming a consistent growth rate each year. The results are found in Figure 1–29, Lines 9 and 10.

Flight Hours. Total flight hours for the HEMS industry were available for 1972 to 1985 (Figure 1–29, Line 8a and 8b). In addition, the average total flight hours per program, excluding PR flight time, were published for 1983 to 1999 (Figure 1–29, Line 5). Total flight hours (less PR flights) for 1993 to 1999 could now be estimated (number of programs X average flight hours per program).

For 1986 to 1992, we had to first estimate the average number of flight hours per program. We relied upon Collett's previously documented average of 1.05 flight hours per patient flight in 1988 when the average loaded flight was 58 miles. To test this hypothesis, we calculated the average flight hours per patient transport from 1993 to 1999 (Figure 1–29, Line 6). Over these seven years, the average was 1.058 flight hours per patient transport—despite the fact that the loaded miles had decreased. Multiplying 1.05 times the average number of patients transported per program per year for 1986 to 1992, we were able to estimate the flight hours needed to normalize our data.

To determine the accuracy of the calculated total flight hours, we compared *AirMed's* average flight hours per program to the results of our HEMS operator survey. For the year 2000, the companies operated 160 programs and 269 dedicated helicopters. Comparing this to our *Flightweb* survey results (231 programs and 377 helicopters), the operators represent 69% of the HEMS programs and 71% of the helicopters. In 1999, the average total flight hours per program was 925 hours for our five operators. This represents a 12% increase over the 821 hours published in *AirMed*. Based upon our operators' survey, the 1998 average was 854 hours. This corresponds to a 5% increase compared to the *AirMed* survey for that same year. Taking into account our earlier estimates regarding

non-patient flight time and PR flight time, these calculated increases (an average of 8.5%) seem accurate. Figure 1–29, Line 7 lists the average *total* flight hours per program from our operators survey results (1998 to 2000) and the calculated values for 1986 to 1997. This is done by multiplying the previously recorded average flight hours per program (Figure 1–29, Line 5) by 1.085. Total flight hours for each year can now be more accurately estimated, as documented in Figure 1–29, Line 8b.

Patients Transported. The journals published data on the total number of patients transported each year from 1980 to 1990. With the number of programs now estimated for each year, the total number of patients transported annually from 1991 through 1999 could also be estimated (number of programs X the average number of patients transported each year).

Accident Data. The yearly accident and fatal accident data (Figure 1–29, Lines 15 and 19) were obtained and summarized from several resources. The references included the NTSB and NASA websites, the CONCERN Network, and personal databases from several industry leaders.

Year 2000. For the year 2000, *AirMed* no longer published their "Annual Transport Statistics," which included the average number of patients transported and hours flown. In order to estimate these numbers, the *AirMed* survey results for the previous five years were averaged. It is interesting to note that our operators' survey shows a decrease in the average flight hours per program to 841 hours, a decrease of 9% compared to 1999 figures.

Year 2001. In order to include the 2001 HEMS accidents in our calculations, additional information was obtained from our aviation operators and aircraft manufacturers. Recognizing that the operators represented approximately two-thirds of the programs and helicopters in our earlier analysis, this seemed an appropriate perspective for year 2001 projections.

Operators were asked for their 2001

total flight time, total number of programs, and total number of helicopters operated. The combined results identified 159 programs and 286 dedicated helicopters. Compared to 2000, this was a decrease of one HEMS program, while 17 additional helicopters were placed in service—an increase of 6%. Follow up with the aircraft manufacturers, however, showed a one-year increase of 13% for the total number of EMS helicopters. Combined total flight hours according to the operators increased at the same rate, showing a gain of 13% over the previous year. These values were used to calculate 2001 data for our comparisons.

Accident Rates

The necessary data is now available to normalize the HEMS data and compare what has occurred each year. Accident rates were calculated using all of the accidents that were included in Figure 1–29. This included patient and non-patient missions. The only medical helicopter accidents excluded were several dual-purpose helicopter accidents, two maintenance flights where the aircraft were not in service to the HEMS program at the time of the accident, and a training flight of a newly hired pilot preparing for his check ride.

The first comparison for the HEMS accidents is a determination of the accident rates per 100,000 flight hours (Figure 1–29, Line 17a). The formula $([100,000 \times \text{number of accidents}] / \text{total flight hours for the year})$ used the total flight hours as calculated with the 8.5% increase (Line 8b) to account for all flight time (patient and non-patient missions). A second accident rates per 100,000 flight hours was calculated (Figure 1–29, Line 17b) using the total flight hours before the increase. The difference between these two accident rates for each year ranged from 0.05 to 1.3 accidents per 100,000 flight hours with an average difference of 0.39 accidents per 100,000 hours. When these two accident rates were graphed together, they virtually overlapped. As a result, we are only including the calculations from Line 17b in our graphic analysis, which depicts the slightly higher rate.

Figure 1–30 shows that there has been a dramatic decrease in the accident rate since the mid-'80s. As the raw data

would predict, the accident rate since 1998 has steadily increased. However, despite this increase, the rate remains roughly one-third of what we experienced in the early to mid-1980s due to the overall increase in flight hours.

Looking at an average accident rate for the past 10 years 1992–2001 (3.53 accidents per 100,000 flight hours), the average HEMS program flying 911 hours per year, would have one accident over 31.1 years of flight time. Changing this calculation to include the accident rates for the past 5 years, (1997–2001), we see a moderate change. We now have a 5-year average of 4.56 accidents per 100,000 flight hours and the prediction for the average program decreases to one accident over 24.1 years. Naturally, if a program flies less, the number of years would go up, and if a program flies more, the time frame would decrease. Another way to propose the likelihood of an accident would be to compare the number of accidents to the number of programs (or helicopters). Again, using the most recent ten years, there has been an average of 7 accidents each year. With 231 dedicated HEMS programs, and assuming all things being equal, we would find a similar prediction of one accident per program every 33 years. If you base this comparison on the number of dedicated helicopters estimated for 2001 (400) rather than programs, the margin now goes up to nearly 57.1 years. Looking at the average number of HEMS accidents (9) for the past five years, we would expect one accident per helicopter every 44.4 years.

The second comparison is looking at the fatal accident rate per 100,000 flight hours (Figure 1–29, Line 21). Here too, in Figure 1–31, we see a dramatic improvement since the early and mid-1980s. Our current rate, despite having gone up slightly over the past few years, is approximately 75% less than our worst years. Once again if we take an average flight program and an average fatal accident rate for the past ten years (1.38 fatal accidents per 100,000 flight hours), we would predict one fatal accident while flying more than 79.3 years. When we focus on the average fatal accident rate for 1997–2001 (1.69) this figure drops to 64.8 years. The final normalized comparison will look at the

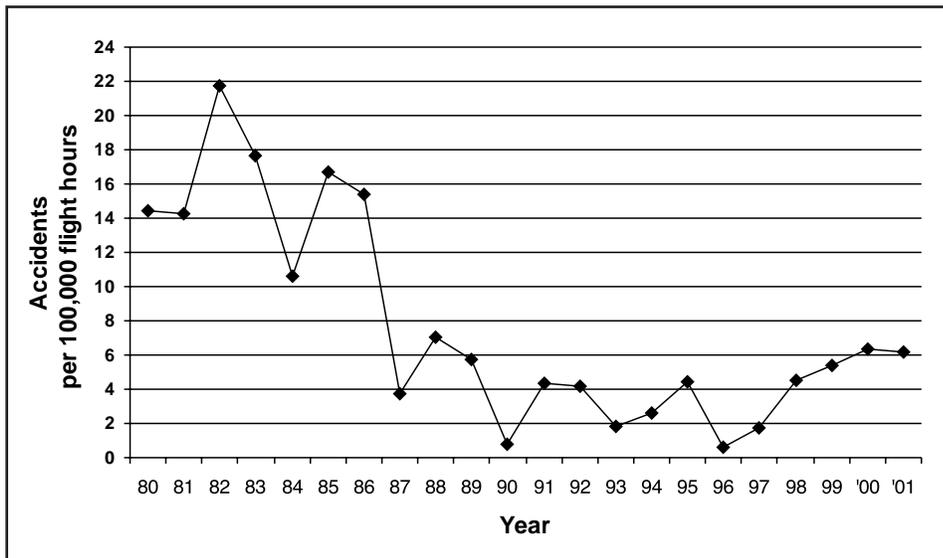


Figure 1–30: Accident Rates for HEMS Operations, 1980 – 2001

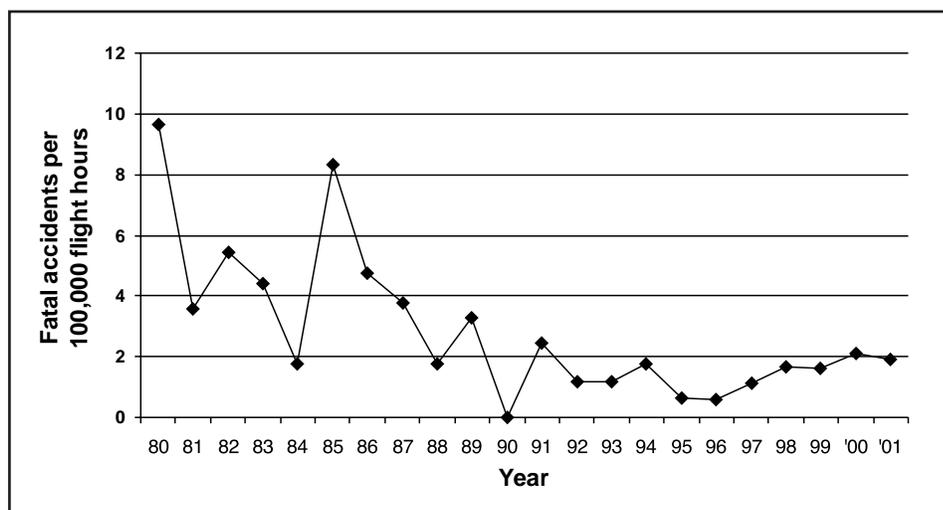


Figure 1–31: Fatal Accident Rates for HEMS Operations, 1980 – 2001

HEMS data in much the same manner as was done in the '80s—comparing the accident rate per 100,000 patients transported (Figure 1–29, Line 23). With a high correlation of flight time per patient transport, Figure 1–32 is very similar to the Figure 1–30.

We would expect similar results if we again look at our average flight program. With a 10-year (1992–2001) average accident rate of 3.89 accidents per 100,000 patients transported and the typical HEMS program flying 882 patients in a year, a program would have one accident while transporting an estimated 25,700 patients over 29.2 years. Calculations for 1997–2001 (4.79 accidents per 100,000 patient transports)

resulted in an estimate of one accident while transporting nearly 21,000 patients over a 23.74 year period.

It may be of interest to note a 1990 study by Rhee et al., that compared the HEMS accident rate in the United States to that of the Federal Republic of Germany. For 1982–1987, Rhee’s calculations found an accident rate in the U.S. of 11.7 per 100,000 flight hours. The calculated accident rate for West Germany was found to be comparable at 10.9 per 100,000 flight hours. The fatal accident rates were also found to be similar. The U.S. rate was 4.7 fatal accidents per 100,000 flight hours while the West German rate was 4.1. In contrast, using our own database and calculations for

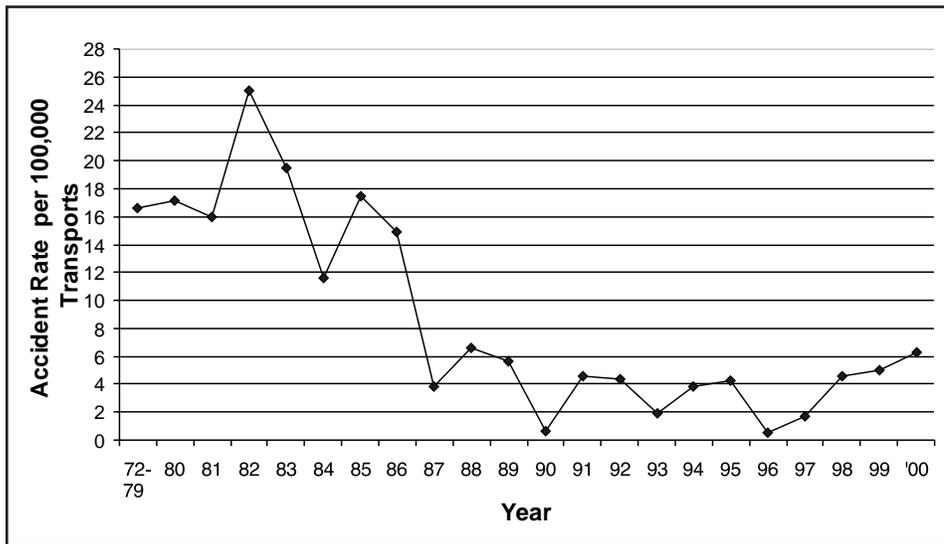


Figure 1-32: HEMS Accident Rate per 100,000 Patient Transports, 1972–2000

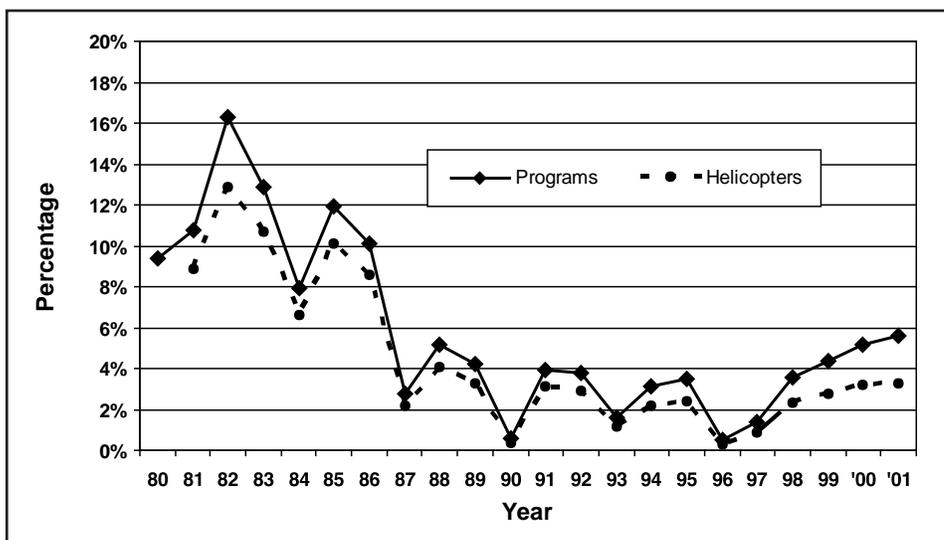


Figure 1-33: Programs and Helicopters with Accidents, 1980–2001

this same time frame (1982–1987), our statistics yield a much higher accident rate of 15.58 per 100,000 flight hours and a fatal accident rate of 5.2.

Percentage of HEMS Programs and Helicopters Involved in Accidents

Data is not available to accurately determine what percentage of HEMS programs have sustained an accident. Over nearly 30 years of civilian HEMS operations, dozens of programs have closed and others have merged operations. However, with the data that we have accumulated to estimate the number of programs and

helicopters each year, we can determine annual percentages with some accuracy. Averaging these annual calculations, we can estimate the overall percentage of HEMS programs and helicopters that have had accidents. These calculations do not take into account the possibility that an individual program may have suffered more than one accident—which has occurred.

The calculated percentage of programs and helicopters that sustained accidents each year since 1980 is shown in Figure 1-29, Lines 18a and 18b. The five accidents that occurred prior to 1980 are not included, as we do not have annual statistics on the number of programs or heli-

copters before 1980. Figure 1-33 shows the wide range for our results. In 1982, an estimated 16.3% of the HEMS programs (8 accidents, 49 programs) were involved in accidents. The safest year was in 1996, when an estimated 0.5% of the programs had an accident (1 accident, 207 programs). Overall, the average annual percentage over 22 years calculates to 5.8% of the programs having had accidents between 1980 through 2001. If you consider only the past five years, an average of 4.1% of the programs have had an accident each year.

Calculating the percentage of helicopters that were involved in HEMS accidents each year finds a high of 12.9% of the HEMS aircraft in 1982 (8 accidents, 62 helicopters). In 1996, there was 1 HEMS accident during a year when an estimated 309 dedicated medical helicopters were in operation, for a total of 0.3%. The average percentage over 22 years calculates to 4.4% of the HEMS fleet. Over the past 5 years, this percentage has averaged 2.5% for each year.

SECTION 2: A COMPARISON OF HEMS TO OTHER TYPES OF AVIATION

Having reviewed HEMS-specific data, this report will now compare HEMS accident and incident data to other types of aviation. This section first looks at two reports and then focuses on various aviation industry statistics. Finally, the accident rates for helicopter air medical transport is compared to other aviation operations.

HELICOPTER EMS vs. ALL HELICOPTER ACCIDENT DATA: 1990–2000

During the 2000 Air Medical Transport Conference (AMTC), Sandra Hart of the NASA-Ames Research Center presented a study that compared characteristics of helicopter EMS accidents with those of all helicopter accidents (EMS and non-EMS) over the

same time period. In March 2001, Hart presented an updated report at the Proceeding of the 11th International Symposium on Aviation Psychology.

In her introduction at AMTC, Hart pointed out that in recent years, the number of HEMS accidents has increased. However, she emphasized that all we have is raw numbers. Accurate exposure data is lacking regarding the number of transports and the number of hours flown by helicopter EMS. Without this, we do not have accurate information to determine if the increase in accidents is related to an increase in the hours flown or whether HEMS had got-

ten less safe. As a result, the data presented in her lecture was based upon raw numbers and percentages rather than as accident rates.

In addition, Hart stated that “aircraft accidents are poor indicators of safety trends due to a low occurrence rate and limited information about what happened. Quite often, the immediate ‘cause’ may have little relationship to the underlying causes. But as risk factors begin to accumulate, something bad was bound to happen.”

An analysis of 1,494 helicopter accidents over a 10-year period beginning in 1990 was conducted by the NASA-Ames

Research Center. The database was obtained by reviewing the NTSB accident and incident reports, looking at narratives, probable cause, occurrences, findings and coded data (e.g., pilot experience, helicopter make/model, visibility, mission). A total of 58 HEMS accidents were identified within this database—both Part 135 (patient-related transports) and Part 91 flights (repositioning, maintenance, etc.). Of interest, 72% of the HEMS accidents were flown under Part 91 and only 30% were on patient-related missions. Some HEMS operations conduct the flight to the patient under Part 91 regulations, while other programs consider all legs of a patient flight to be Part 135.

Figure 2-1 illustrates the number of accidents that were included for each year in the Ames report. Several 1999 and 2000 accidents lacked NTSB final reports and were not included.

When the Accidents Occur

When comparing the data, approximately 53% of the HEMS accidents occurred between dusk and dawn while only 9% of all helicopter accidents occurred at night. It is estimated that only 5% of all helicopter flights are at night.

Hart found that nearly five times as many HEMS accidents occurred in IMC conditions (24% compared to 5% for all helicopter accidents), with nearly all of them involving inadvertent flight into IMC conditions. This was consistent with the previous NTSB study. Neither snow nor rain was an identified problem, with very few helicopter accidents occurring with visible precipitation. This could be due to the fact that fewer helicopter flights occur during these types of weather conditions. Another possibility could be that pilots are more careful when they can see visible precipitation (rain or snow). In contrast, deteriorating weather conditions (decreasing ceilings or fog developing) may be less obvious.

Of the 58 accidents, weather conditions were cited as a contributing factor 29 times. It is important to note that these were *factors* and not the cause of the accidents. In some cases there was more than one weather factor cited with

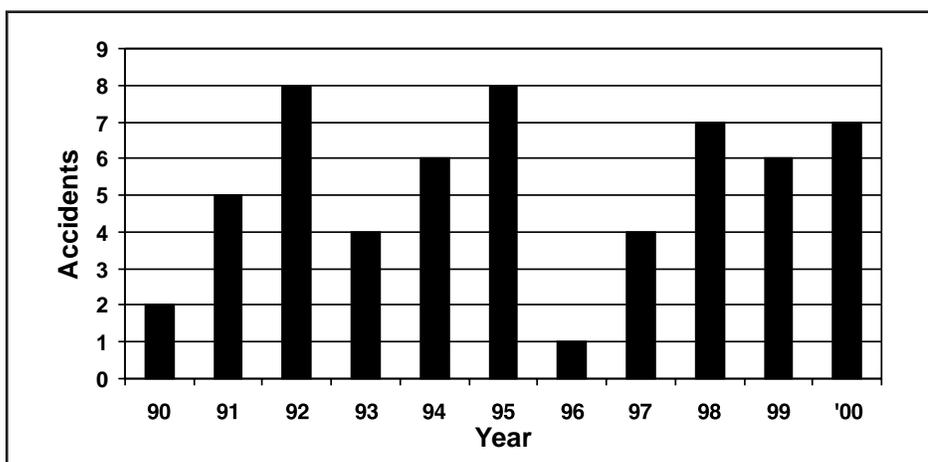


Figure 2-1: Number of HEMS Accidents per Year
Adapted from: Hart, Conference presentations, 2000/2001

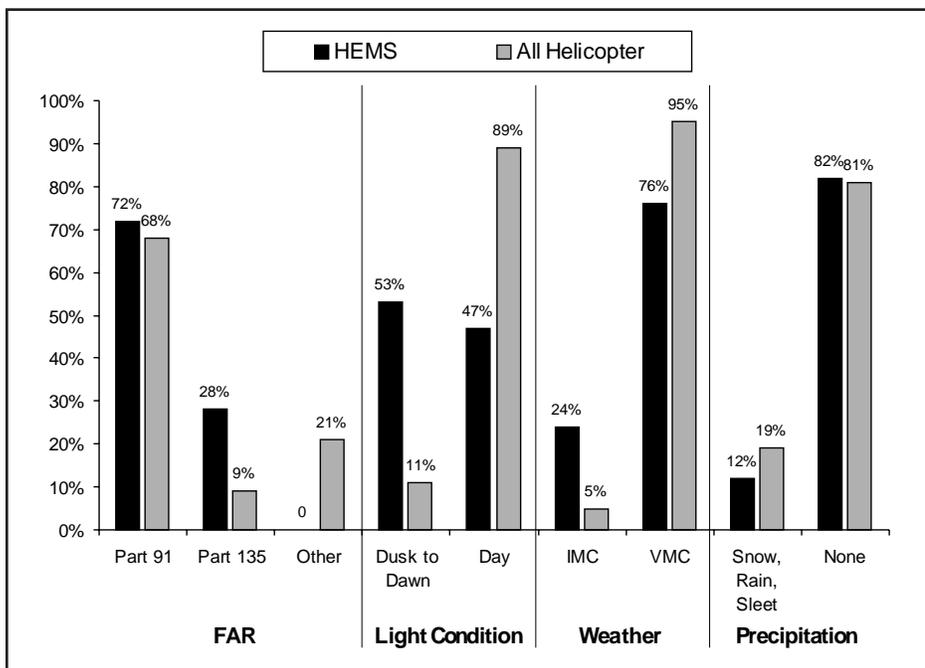


Figure 2-2: When Accidents Occur (HEMS: n=58; All Helicopters: n=1,494)
Adapted from: Hart, Conference presentations, 2000/2001

regard to an accident or incident. Weather is therefore likely to add to the risk of a flight. It may not cause the accident, but it may increase the likelihood that an accident could occur. Weather was cited only twice as the *cause of an accident*.

With regard to the phase of flight, there are some significant differences when comparing HEMS to all helicopter accidents. For all helicopter accidents the highest percentage of accidents were seen during landing (25%), maneuvering (21%), cruise (15%), hovering (11%), and takeoff (11%). This is significantly different from HEMS accidents that occurred most commonly during cruise (24%), takeoff (19%), approach (16%), and landing (14%). Figure 2-3 shows the distribution of accidents during the various phases of flight.

Pilot Experience

Experience of the pilots was carefully reviewed by the Ames study. In general the HEMS pilots averaged slightly fewer total hours than the total pilot database (6,307 vs. 6,424). However 79% of the HEMS pilots' hours (5,010) were in helicopters. The overall group included commercial fixed-wing pilots who did much less time in helicopter aviation (66% or 4,230 hours). HEMS pilots averaged fewer hours (753) in the make/model helicopter they were flying at the time of the accident compared to pilots for all of the helicopter accidents (1,273). In addition, unlike the NTSB report, pilot fatigue was not found to be a significant factor in these HEMS accidents. According to the study, the average HEMS pilot had flown only 1.88 hours in the 24 hours prior to their accident which was less than the average (3.00) for the "all helicopter accident" group.

The Ames researchers found a significant difference with regard to instrument ratings. EMS pilots were far more likely to have an instrument rating than all helicopter pilots involved in accidents. They may not have been current and they may not have been flying helicopters that were IFR equipped, but their training and experience was noted. According to Hart, while this additional training and experience should be con-

sidered an advantage to the EMS helicopter pilots, it may have worked as a disadvantage if the pilots felt that their training and experience would allow them to "push the envelope a little bit more."

Vehicle Characteristics

There were more HEMS accidents involving twin-engine helicopters than single-engine helicopters (63% vs. 36%, respectively). This is in contrast to all the accidents where the majority of the aircraft were single-engine aircraft (89%). It is important to note that no mention or comparison is made with regard to the percentage of single- vs. twin-engine helicopters in operation—only the comparison of those involved in accidents.

Accident Characteristics

HEMS accidents have a much higher likelihood of resulting in serious injuries or fatalities than other helicopter accidents. Of the 58 accidents studied, 38% resulted in at least one fatality compared to 17% for the overall database. These results are similar to the previous studies. While there tended to be very few post-crash fires in either group, aircraft in both groups were either destroyed or seriously damaged at very high rates (92% for HEMS vs. 97% for all accidents). HEMS aircraft, however, were destroyed at a much higher rate. Figure 2-5 shows the accident characteristics for both groups.

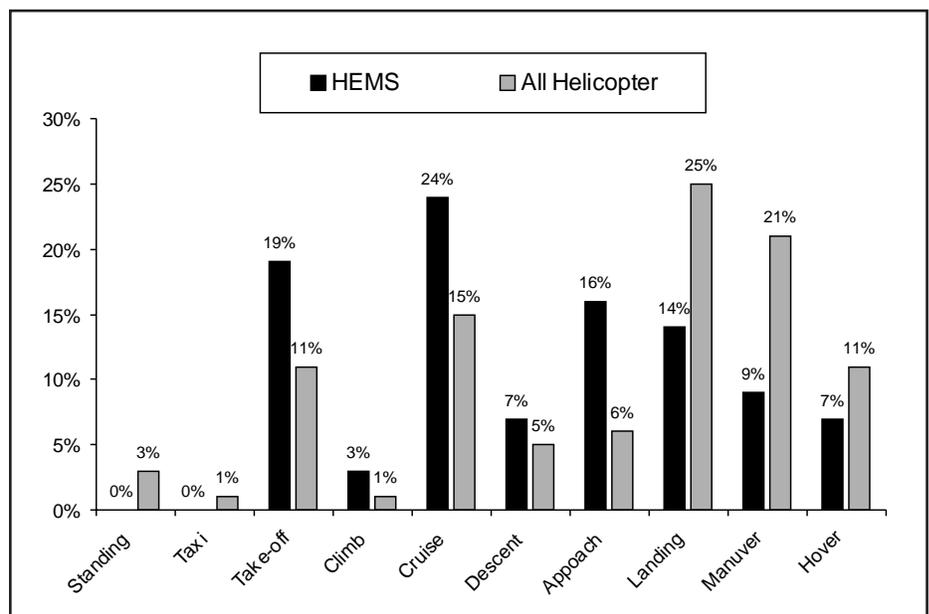


Figure 2-3: Phase of Flight (HEMS: n=58; All Helicopters: n=1,494
Adapted from: Hart, Conference presentations, 2000/2001

	EMS		All Helicopter	
	Average	Range	Average	Range
Total Hours	6,307	3,000–19,275	6,424	29–34,886
Helicopter Hours	5,010	27–17,380	4,230	8–25,000
Hours in Make	753	16–3,620	1,273	3–8,918
Instrument Hours	269	0–1,647	203	0–3,613
Prior 24 hours	1.47	0–6	3.00	0–15

Figure 2-4: Pilot Experience
Adapted from: Hart, Conference presentations, 2000/2001

Chain of Events and First Events

Hart's report emphasized that accidents are not caused by a single event. In most accidents, numerous risk factors can be identified. An accident might have an obvious identifiable cause, but there are likely to have been numerous risk factors that contributed to the event or the severity of the event. Acting on any of these risks might prevent an accident from happening or lessen the severity of the accident.

When the NTSB looks at accident data, they pay particular interest to the "first events"—the first obvious and measurable event that can be considered an accident. It is not the first occurrence in the chain of events that leads to the accident. Rather, it corresponds to the first event that would be considered evidence that an accident has taken place. First events are not causes. Their analysis tells us *what* has happened, but do not tell you *why* it happened.

The most common first event in HEMS was an in-flight collision with terrain, with wires being the primary offender. EMS helicopters were more than twice as likely to strike an object or terrain and nearly five times more likely to have an encounter with inclement weather. Relatively few of the HEMS accidents were caused by low engine power, airframe, or component failures compared to the all helicopter accident group. Hart concluded that this seems to suggest that, in general, EMS helicopters are well maintained.

The Ames study presented a cascading chain of events of what happens when an accident occurs. An in-flight encounter with weather is rarely the cause of an accident but is often the first event. It leads to an in-flight collision with an object or terrain or to a loss of engine power. Another frequent first or second event is loss of control in flight, which may follow some type of system failure (which is rare).

Cause and Contributing Factors of Accidents

When the NTSB finalizes their accident reports they try to identify a cause of each accident. This is not necessarily the only event that contributed to the acci-

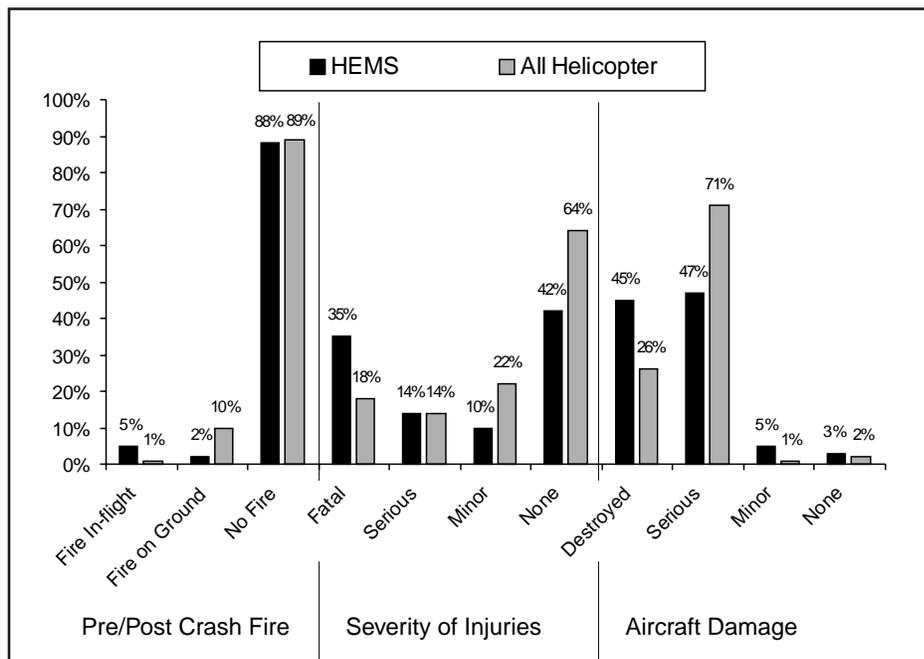


Figure 2-5: Accident Characteristics (HEMS: n=58; All Helicopters: n=1,494)
Adapted from: Hart, Conference presentations, 2000/2001

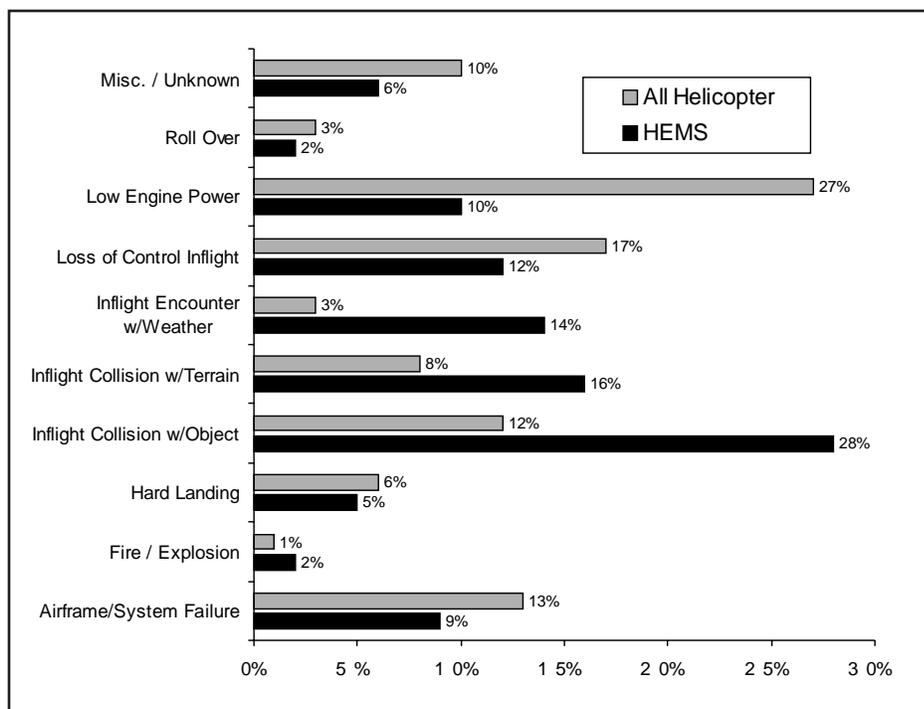


Figure 2-6: First Events (HEMS: n=58; All Helicopters: n=1,494)
Adapted from: Hart, Conference presentations, 2000/2001

dent. Pilot-related factors (human factors) were cited 50 times in the 58 accidents. These factors included operating with known deficiencies, inadequate pre-flight planning, inability to evaluate the weather, inadvertent flight into IMC, failure to follow procedures, spatial disorientation, lack of experience, and

failure to maintain proper speed, altitude, rate of descent or climb, or RPM. Of interest, Hart pointed out that in very few of these accidents was it identified that the pilot deviated from the FARs or company regulations. This is significantly different than the data reviewed earlier in the ASRS report.

Aircraft-related causes of the 58 HEMS accidents were cited 22 times, while fuel-related problems were cited twice. Weather was cited only once.

There are a number of contributing factors that increase the risk for an accident. Many of these are related to weather (e.g., icing conditions, clouds, fog, rain, snow, sleet), which was cited 29 times as a contributing factor in the 58 accidents. Person-related contributing factors were cited 25 times, which included distractions, pressure felt by the pilot, as well as the items listed under “causes.” Terrain, which was cited 24 times, was another consideration and flying at night (dusk to dawn) was cited 18 times.

FACTORS RELATED TO OCCUPANT CRASH SURVIVAL IN EMS HELICOPTERS

Much of what we have been reviewing has dealt with the associated risks and events surrounding accidents that have occurred in the past. It is also essential to assess the relative occupational risk to the crewmembers of EMS helicopters. Robert Dodd’s 1992 Ph.D. dissertation evaluated the incidence and seriousness of crash-related injuries among EMS helicopter occupants in *survivable* crashes.

The study found that main cabin occupants in EMS helicopters have nearly 4.5 times the risk of serious injury or death in survivable crashes when compared to a comparable population of occupants in the main cabin of non-EMS air taxi helicopters. For front seat occupants, he found that there was no significant difference in injury risk between the two groups. This seemed to support his premise that EMS aircraft modifications, which are generally limited to the main cabin, were directly associated with the risk of injury and may contribute to occupant injury and death in otherwise survival crashes.

For his study, Dodd reviewed 75 EMS accidents from 1978–1983 and 1983–1989 (with 241 occupants) and 147 non-EMS helicopter accidents from 1983–1989 with 485 occupants. His comprehensive review and analysis of

	Total		Non-survivable		Survivable	
	Crashes	Occupants	Crashes	Occupants	Crashes	Occupants
EMS	75	241	24	70	51	171
Non-EMS	147	485	20	50	127	435

Figure 2–7: Survivable and Non-survivable EMS and Non-EMS Crashes
Adapted from: Dodd, unpublished dissertation, 1992

Occupant Location	Serious Back Injuries (%)		Serious Head Injuries (%)		Minor Head Injuries (%)		Internal Injuries (%)		Fractures (%)	
	EMS	Non-EMS	EMS	Non-EMS	EMS	Non-EMS	EMS	Non-EMS	EMS	Non-EMS
Pilot	4.5	10.8	2.3	2.4	0	3.6	0	0	2.3	7.2
Front Seat	15.4	2.7	7.8	5.4	0	2.7	11.5	0	3.8	8.1
Main Cabin	28.6	9.2	14.3	1.3	5.3	1.3	7.1	2.6	10.7	5.3
Patient	14	N/A	7.1	N/A	0	N/A	0	N/A	7.1	N/A

Figure 2–8: Distribution of Injuries in Survivable Crashes—EMS vs. Non-EMS Crashes
Adapted from: Dodd, unpublished dissertation, 1992

available reports identified survivable vs. non-survivable crashes and occupants, as seen in Figure 2–7.

Comparing occupant location in survivable accidents with specific injury patterns, Dodd concluded that EMS main cabin occupants were at a higher risk for serious back injuries and serious head injuries. Figure 2–8 compares the percentage of occupants with specific injuries and where they were seated in the helicopter.

Dodd’s research included written surveys that were sent to survivors. Twelve injured EMS occupants indicated injuries that were the result of striking medical equipment inside the helicopter during the crash. This equipment included the stretcher, cardiac monitor, medical panel, oxygen tanks, and portable radio.

As part of his research, Dodd evaluated numerous variables to determine how they had influenced injuries. The variables included crash severity, post-crash fire, number of engines, helicopter weight, light conditions, use of shoulder harness, cause of the crash, age, and sex. For each of these variables, he calculated the relative risk of injury for EMS occupants compared to non-EMS occupants in survivable crashes. Dodd found that there was a significantly greater risk of injury (significant relative risk) in HEMS accidents compared to non-EMS acci-

dents: where there was a post-crash fire; in single-engine helicopters; with helicopters weighing < 4,500 pounds; during daylight conditions; with EMS occupants who did not wear a shoulder harness; and mechanical-related crashes. There was a marginal relative risk of injury in helicopters that weighed > 4,500 pounds.

In contrast, he found no significant relative risk of injury in: the absence of post-crash fire; twin-engine helicopters; during dark (night) conditions; or crashes caused by loss of control, wire strikes, or bad weather. Even though significantly more EMS accidents (32%) occurred in bad weather compared to the non-EMS study group (14%), there was not a significant increase in the risk of injury. There was also no correlation between injury and the age or sex of the occupants between the two groups.

Dodd also evaluated the severity of the accidents and classified them as Crash Severity Level 1 (hard landing), Crash Severity Level 2 (hard landing with substantial damage), and Crash Severity Level 3 (high vertical impact or cruise collision with ground). Level 1 accidents resulted in no injuries to EMS occupants and only one non-EMS injury. Level 2 accidents yielded a significant relative risk for passengers in the main EMS cabin, but a non-significant risk for front-seat passengers. In Level 3 accidents, the significant

relative risk for main cabin occupants was even greater in EMS aircraft.

Dodd's calculations of accident rates were similar to the NTSB report that had come out four years earlier. He found that EMS helicopters had an accident rate of 11.84 per 100,000 hours of flight. This is more than 2.5 times that of non-EMS air taxi helicopter operations that were found to have an accident rate of 4.43 per 100,000 flight hours. While Dodd did not compare fatal accident rates, he did compare the percentage of occupant fatalities for his two study groups. He found that 32% of the EMS occupants suffered fatal injuries, while only 9% of the non-EMS occupants died—a rate that is 3.5 times greater for the EMS group.

Dodd's report makes a convincing statement for addressing accident survival as well as accident prevention. EMS personnel are injured more frequently and more severely in survivable HEMS accidents when compared to occupants of non-EMS helicopter crashes.

Dodd presented a 1991 study by Crowley that evaluated the use of helmets in survivable military crashes. Crowley found that occupants without helmets were 4 times more likely to suffer a serious head injury and 6 times more likely to suffer a fatal head injury than occupants with helmets. Limiting the comparison to the main cabin increases the risk. Main cabin occupants with no helmet were found to be at 5 times the risk for a serious head injury and 7.5 times the risk for a fatal head injury than their helmeted counterparts. While Crowley's study was based on military data, he suggested that it might also be applicable to survivable HEMS accidents.

Another series of studies for the U.S. Army concluded that back injuries were the most common injury suffered by occupants in survivable helicopter accidents. These results are consistent with Dodd's findings. The Army studies found that shoulder harnesses were an important factor in reducing the incidence and severity of serious back injuries.

Dodd concluded that the increased risk of injury to main cabin occupants of EMS helicopters represented an occupational risk that had not previously been addressed in the literature. He concluded that the EMS helicopter was a very haz-

ardous place, even in a survivable crash. Dodd suggests that the use of energy attenuating seats, in combination with lap and double shoulder harnesses, and intelligently designed interiors could dramatically improve occupant injury tolerance.

HELICOPTER ACCIDENT ANALYSIS TEAM

This next study which is not limited to HEMS, reviews a series of helicopter accidents to determine what happened and what could be done to break the chain of events that lead to accidents. The Helicopter Accident Analysis Team (HAAT), was a cooperative effort involving the Department of Defense (DoD) the Federal Aviation Administration/Department of Transportation (FAA/DoT), and the National Aeronautics and Space Administration (NASA). It began in February of 1997, as mandated by the White House Gore Commission on Aviation Safety.

The approach in this analysis is similar to the "Air Medical Accident Analysis" described in Section 1, but this study included EMS and non-EMS helicopters. A *balanced sample* of 34 helicopter accidents was selected from the 1990 to 1996

NTSB database of helicopter accidents and incidents. HEMS accidents selected were those that involved a patient transport mission at the time of the accident.

Three subgroups worked independently to address different aspects of these accidents. First they developed a sense of what happened—the *chain of events* that led to each of the accidents. Next they identified the *problems*—issues with respect to the aircraft, environment, pilot actions, maintenance, air traffic control, and the quality of the information in the report itself. Finally, they brainstormed about what might have prevented the accident entirely or mitigated its severity—the *interventions*. The goal of the HAAT analysis was to propose technology, training, and institutional interventions that might have eliminated one or more "links" in those chains of events, thereby averting an accident or decreasing the severity of an accident that does occur.

Chain of Events

The number of events identified for any particular accident ranged from 5 to 33, with an average of 16 events per accident. This resulted in a total of 536 events. Five different categories of events were identified. Figure 2-9 lists the categories and examples of the events.

Category	Examples of Events
Preliminary events	Definition: Factors that influenced the accident but were not directly related to actions taken by those involved in the accident Examples: Pilot's health, pilot's experience, adverse weather
Preflight events	Definition: Events that occurred prior to departure of the accident flight that could have influenced the outcome Examples: Failing to obtain a weather briefing preflight or ensuring that the aircraft had enough fuel
Flight-related events	Definition: Events or actions that occurred during the flight and were associated with the accident Examples: Continued flight into adverse weather, poor air traffic control vectoring
Emergency-related events	Definition: Events that occurred during the emergency/accident sequence or precipitated the sequence Examples: Poor landing site selection, wire strike, fuel starvation
Survival-related events	Definition: Events or actions that did influence, or could have influenced, occupant survival after the accident Examples: Helmet use, delayed rescue, inoperative ELTs

Figure 2-9: Chain of Events Categories identified by HAAT

Adapted from: Helicopter Accident Analysis Team. Final Report, NASA-Ames Research Center, 1998

Problems

The accident analysis identified the number of problems for each accident, ranging from a low of 3 to a high of 21. There was an average of 16 problems per accident, resulting in a total of 442 entries. Figure 2–10 illustrates the categories of problems identified and specific problems within each category.

Interventions

After identifying the problems, interventions were identified that could have prevented the accident or lessened its severity. The number of interventions identified for individual accidents ranged from 4 to 25, averaging 13 per accident. There were a total of 416 possible interventions identified across all the accidents. Figure 2–11 reviews the categories of interventions and the specific proposals made by HAAT.

The previously presented “Air Medical Accident Analysis” evaluated the effectiveness and feasibility of each of their recommended interventions. That was not done in this study. Instead, the final step of the HAAT analysis was the proposal of 26 specific *Safety Investment Areas* that were derived from their identified interventions. Rather than a single statement, each area had identified goals, background, opportunities for reducing future fatalities, research needs, timing, related work, and the primary beneficiaries. Their emphasis was no longer on specific interventions that might have broken the chain of events for a specific accident. Rather, the Safety Investments were more global and goal oriented. Their recommendations included specific goals directed toward the development of research and technology to enhance safety and to improve procedures and practices. Safety Investment Areas were identified in helicopter design and performance, situation displays, pilot aiding and automation, pilot training, improving the flight environment, crash survivability, and the improvement of safety data and analysis.

Problems Associated with...	Problems Identified
Pre-Flight Planning	Aircraft / operating limits not considered Weather or wind not considered Mission requirements / contingencies ignored Pre-flight process inadequate Passenger safety brief inadequate
Safety Culture of the Organization	Management policies / oversight inadequate Safety program / risk management inadequate Helicopter not IFR-equipped Problems with pilot’s health not addressed
Inadequate Training or Experience	Emergency training inadequate Special operations training inadequate Training inadequate for inadvertent IMC Pilot inexperienced with area, mission, vehicle
Maintenance	Tools to detect failing parts inadequate Bogus, surplus, unapproved parts used Improper procedures/supervision Inadequate documentation Components used not built to manufacturer’s specifications
Infrastructure	Inadequate oversight IFR system incompatible with helicopter missions Part 91 vs. Part 135 passenger-carrying operations Inadequate tower/wire markings
Pilot Judgment and Actions	Sense of urgency led to risk-taking Diverted attention, distraction Flight profile unsafe for conditions Poor cockpit resource management Perceptual judgment errors Procedural errors Pilot control/handling deficiencies Used unauthorized equipment
Communications	Coordination with ground personnel Coordination with ATC Coordination with other pilots
Pilot Situation Awareness	Aircraft position and hazards Aircraft state Local and en route weather
Vehicle Part or System Failures	Main rotor problem Engine failures (partial or total) Gear box failure Tail rotor/tail boom failures
Post-crash Survivability	Safety equipment not installed/failed Passenger/crew survival gear not used Vehicle did not withstand impact Vehicle sank and/or capsized Post-crash fire ELT inoperative/damaged by impact Inaccessible accident site/bad weather No flight following—slow to locate site

Figure 2–10: Problems Identified by HAAT

Adapted from: Helicopter Accident Analysis Team. Final Report, NASA-Ames Research Center, 1998

Categories	Proposed Interventions
Safety Culture Solutions	Adequately equip rotorcraft for mission Develop an inadvertent IMC policy Formalize passenger pre-flight briefing Develop clearly defined company policies
Training Interventions	Basic training materials/syllabus Aeronautical decision-making training Crew resource management training Training to recognize and resolve emergencies Ground personnel training Recovery from IMC/IFR training Simulation facilities for rotorcraft training Training for unique ops/maneuvers/missions
Maintenance Solutions	Non-destructive inspection techniques Improved maintenance procedures and quality control
Helicopter Design and Performance Solutions	Health and Usage Monitoring Systems Real-time performance monitoring Wire cutters/hardened blades Icing protection Miscellaneous design improvements
Helicopter Situation Display Solutions	Ground proximity warning system for rotorcraft Electronic map/position Obstacle detection and alerting Radar alt/distance from ground/water Enhanced/synthetic vision Weather display and alerting
Pilot Aiding and Automation Interventions	Autorotation display/aid Attitude hold/stabilization Automatic flight following PC-based Pre-Flight Planner and PC-based Risk Assess System
Infrastructure Interventions	Operating requirements for commercial rotorcraft Regulations/procedures for inadvertent IMC Review tower/wire marking requirements Navigation/landing systems for rotorcraft Review training and qualification requirements Requirements for company safety program Special operations regulations
Post-Crash Survival Interventions	Improved crashworthiness Crash-survivable ELT Survival equipment Restraint systems Flotation systems Crash-resistant fuel system Underwater egress training
Improved Reporting Interventions	Cockpit voice recorder/flight data recorder Improved NTSB accident forms Improved data acquisition Data dissemination/feedback to industry Inflight audio-visual recording in cockpit

Figure 2–11: Interventions Proposed by HAAT
Adapted from: Helicopter Accident Analysis Team. Final Report, NASA-Ames Research Center, 1998

HEMS VS. OTHER AVIATION OPERATIONS

Background

Generally speaking, there are three major categories of aviation regulated by the FAA. Part 135 corresponds to “air taxi” and is classified as *Scheduled* (commuter flights with fewer than 10 seats) or *Non-scheduled*, which includes air medical transport and other on-demand air taxi services. Part 121 aviation governs the airlines, both scheduled and non-scheduled (charter) airlines. The third category is General Aviation (Part 91), typically characterized by recreational (personal) flying, instructional, business, corporate, public use, and other vital services. Figure 2–12 summarizes the number and types of aircraft that were operated under the different regulations in 1998/1999.

As Figure 2–12 shows, helicopters account for a very small portion of aviation operations. Based upon our 1998/1999 statistics, EMS helicopters accounted for an estimated 5% of all helicopters and approximately 48% of the on-demand helicopters in operation. In 1980 there were an estimated 20,750 HEMS flight hours. By 1990, this increased to approximately 140,500. In 2001, HEMS hours were estimated at nearly 217,500 while all helicopters flew approximately 2.4 million flight hours, general aviation flew 26.2 million hours, Part 135 operations accounted for nearly 3.7 million flight hours, and Part 121 airlines flew 16.7 million hours.

HEMS, a Part 135 on-demand air taxi, is certainly a unique form of aviation. There are some similarities with other 135 operations, but also some similarities with General Aviation (Part 91). In fact, as Hart pointed out in her study, many of the HEMS accidents were operating under Part 91 at the time of their accident (e.g., ferry flight, reposition, instruction).

In general aviation (GA), personal flights are consistently the most dangerous. An estimated 44% of all flying is done for recreational or personal reasons and results in nearly 65% of the fatal accidents. In contrast, business flying (i.e., business people who are not professional pilots), accounts for approximately 14% of the GA flight hours, but only accounts for 6% of the fatal accidents. Instructional flying, with 22% of the flight time, results in more than 8% of the fatal accidents. Corporate flying represents only 6% of GA flight hours and had a fatal accident rate of less than 1%. Business and corporate pilots may be more willing to scrub a trip, may fly more reliable equipment, or may have more experience. Likely, it is a combination of all these factors.

In significant contrast to HEMS accidents, nearly 70% of all general aviation (Part 91) accidents are “fender benders” and result in little or no injury. Like HEMS accidents, however, the majority of accidents (more than 70%) were pilot-related. Typically, GA takeoffs and landings account for less than 5% of a typical cross-country flight. However, an estimated 50–70% of the GA accidents occurred during takeoffs and landings. Like HEMS, weather-related accidents were more likely to be fatal than accidents with any other cause. In 2000, nearly 90% of these weather-related accidents resulted in fatalities.

Raw data and normalized statistics are available from the FAA for the different types of aviation operations. Figures 2–14 to 2–16 provide statistics from 1982 to 2001 with regard to number of accidents (total and fatal), flight hours, and annual accident rates for each category. Figures 2–17 and 2–19 graph the accident rates for side-by-side comparison.

In general, the FAA data for this 20-year period shows:

- Helicopter and general aviation accident rates are much higher than all other aviation operations, followed by non-scheduled Part 135 operations.
- The helicopter accident rate has fluctuated from a low of 6.17 accidents per 100,000 flight hours to a high of 12.26.

	Airlines (Part 121), 1998	On-Demand Air Taxi (Part 135), 1999	General Aviation (Part 91), 1999
Experimental		30	20,493
Piston Single-Engine	167	652	150,081
Piston Twin-Engine	44	1,607	19,469
Turboprop Single-Engine		75	943
Turboprop Multiengine	1,837	860	3,802
Turbojet	5,108	496	6,625
Helicopter	3	746	6,701
Total	7,159	4,466	208,114

Figure 2–12: Aircraft in Operation, 1998/1999

Adapted from: *The Nall Report 2001*, AOPA, <http://www.aopa.org/asff/publications/01nall.pdf> and *The Nall Report 2000*, AOPA, <http://www.aopa.org/asff/publications/00nall.pdf>

Operation	Percent of Flying (1999)	Percent of Total Accidents (2000)	Percent of Fatal Accidents (2000)
Personal	44.3	67.4	64.4
Instructional	22.1	13.1	8.2
Aerial Application	4.8	6.0	5.0
Business	13.6	4.0	6.1
Positioning	—	1.7	2.3
Ferry	—	1.0	0.3
Public use	2.2	0.7	0.9
Other work use	2.2	1.0	1.2
Aerial Observation	4.1	0.4	0.3
Corporate	5.5	0.4	0.9
Other/unknown	1.1	4.4	10.2

Figure 2–13: General Aviation Accident Data, 1999/2000

Adapted from: *The Nall Report*, 2001, www.aopa.org/asff/publications/01nall.pdf

- General aviation has seen a general decrease in its accident rate.
- From 1982–1992, general aviation had the highest fatality rate among the various aviation operations. Beginning with 1993, helicopter operations have had the highest fatality rate in 7 of the last 9 years.
- Scheduled Part 135 operations have a very consistent and low accident rate from 1983 through 1996. The past five years, however, have seen a significant increase in this rate.

A Normalized Statistical Comparison

With all of this data, it is now possible to compare the different types of aviation operations. We have already estimated the accident and fatality rates per 100,000 flight hours for HEMS. These rates can now be included for a more

meaningful comparison. It should be noted that we are beginning in 1982 rather than in 1980, as we did with the earlier HEMS graphs.

As the graphs indicate, accident rates for HEMS, all helicopters, and general aviation have always been higher than airline rates. There are many factors that contribute to this difference. In general, these three types of aviation operations involve risks that are not in common with the airlines. These differences include:

- Helicopters and general aviation pilots conduct a wider range of operations, often with less regulation and fewer support services.
- There is a wider variance in pilot qualifications and training.
- There are fewer cockpit resources. Air carrier operations require at least two pilots, while most general aviation and helicopter operation are single pilot.

U.S. General Aviation							Helicopter					
Year	Accidents			Flight Hours	Accidents per 100,000 Flight Hours		Accidents			Flight Hours	Accidents Per 100,000 Flight Hours	
	All	Fatal	Fatalities		All	Fatal	All	Fatal	Fatalities		All	Fatal
1982	3,233	591	1,187	29,640,000	10.90	1.99	255	41	66	2,350,000	10.85	1.74
1983	3,076	555	1,068	28,673,000	10.72	1.94	234	35	55	2,272,000	10.30	1.84
1984	3,017	545	1,042	29,099,000	10.36	1.87	224	38	61	2,495,000	8.98	1.52
1985	2,739	498	956	28,322,000	9.66	1.75	205	36	50	2,154,000	9.52	1.67
1986	2,581	474	967	27,073,000	9.53	1.75	190	39	81	2,625,000	7.24	1.49
1987	2,494	446	837	26,972,000	9.24	1.65	180	28	44	2,283,000	7.88	1.23
1988	2,387	460	797	27,446,000	8.69	1.68	179	21	27	2,707,000	6.61	0.78
1989	2,242	431	768	27,920,000	8.01	1.53	187	30	44	2,829,000	6.61	1.06
1990	2,241	443	767	28,510,000	7.86	1.55	195	25	28	2,392,000	8.15	1.05
1991	2,197	438	799	27,678,000	7.93	1.58	170	30	51	2,756,000	6.17	1.09
1992	2,111	451	867	24,780,000	8.51	1.82	179	41	72	2,282,000	7.84	1.80
1993	2,063	400	740	22,796,000	9.05	1.75	180	37	71	1,833,000	9.82	2.02
1994	2,022	404	730	22,235,000	9.08	1.81	218	44	79	1,777,000	12.26	2.45
1995	2,056	413	735	24,906,000	8.24	1.65	161	25	45	1,961,000	8.21	1.27
1996	1,908	361	636	24,881,000	7.67	1.45	176	32	55	2,120,000	8.29	1.51
1997	1,845	350	631	25,591,000	7.21	1.36	164	28	46	2,084,000	7.87	1.34
1998	1,904	364	624	25,518,000	7.45	1.42	191	34	66	2,138,000	8.93	1.59
1999	1,906	340	619	29,713,000	6.41	1.14	198	31	57	2,171,000	9.12	1.43
2000	1,838	343	594	29,057,000	6.33	1.18	206	35	63	2,472,000	8.33	1.42
2001	1,721	321	553	26,220,000	6.56	1.22	182	29	51	2,381,000	7.64	1.22

Source: www.ntsb.gov/aviation/Table10.htm

Source: www.rotor.com/safety/stats70.01.xls

Figure 2-14: U.S. General Aviation and Helicopter—Accidents, Fatalities and Rates: 1982 through 2001

Part 135: Scheduled							Part 135: Non-scheduled					
Year	Accidents			Flight Hours	Accidents per 100,000 Flight Hours		Accidents			Flight Hours	Accidents per 100,000 Flight Hours	
	All	Fatal	Fatalities		All	Fatal	All	Fatal	Fatalities		All	Fatal
1982	26	5	14	1,299,748	2.000	0.385	132	31	72	3,008,000	4.39	1.03
1983	16	2	11	1,510,908	1.059	0.132	142	27	62	2,378,000	5.97	1.14
1984	22	7	48	1,745,762	1.260	0.401	146	23	52	2,843,000	5.14	0.81
1985	18	7	37	1,737,106	1.036	0.403	157	35	76	2,570,000	6.11	1.36
1986	14	2	4	1,724,586	0.812	0.116	118	31	65	2,690,000	4.39	1.15
1987	33	10	59	1,946,349	1.695	0.514	96	30	65	2,657,000	3.61	1.13
1988	18	2	21	2,092,689	0.860	0.096	102	28	59	2,632,000	3.88	1.06
1989	19	5	31	2,240,555	0.848	0.223	110	25	83	3,020,000	3.64	0.83
1990	15	3	6	2,341,760	0.641	0.128	107	29	51	2,249,000	4.76	1.29
1991	23	8	99	2,291,581	1.004	0.349	88	28	78	2,241,000	3.93	1.25
1992	23	7	21	2,335,349	0.942	0.300	76	24	68	2,844,000	2.67	0.84
1993	16	4	24	2,638,347	0.606	0.152	69	19	42	2,324,000	2.97	0.82
1994	10	3	25	2,784,129	0.359	0.108	85	26	63	2,465,000	3.45	1.05
1995	12	2	9	2,627,866	0.457	0.076	75	24	52	2,486,000	3.02	0.97
1996	11	1	14	2,756,755	0.399	0.036	90	29	63	3,220,000	2.80	0.90
1997	16	5	46	982,764	1.628	0.509	82	15	39	3,098,000	2.65	0.48
1998	8	0	0	353,670	2.262	-	77	17	45	3,802,000	2.03	0.45
1999	13	5	12	342,731	3.793	1.459	73	12	38	3,298,000	2.21	0.36
2000	12	1	5	373,649	3.212	0.268	81	22	71	3,553,000	2.28	0.62
2001	7	2	13	330,500	2.118	0.605	72	18	60	3,400,000	2.12	0.53

Source: www.ntsb.gov/aviation/Table8.htm

Source: www.ntsb.gov/aviation/Table8.htm

Figure 2-15: U.S. Air Carriers Operating Under Part 135—Accidents, Fatalities and Rates, 1982 through 2001 (Since March 20, 1997 only aircraft with fewer than 10 seats)

Year	Part 121: Scheduled Service						Part 121: Nonscheduled Service					
	Accidents			Flight Hours	Accidents per 100,000 Flight Hours		Accidents			Flight Hours	Accidents per 100,000 Flight Hours	
	All	Fatal	Fatalities		All	Fatal	All	Fatal	Fatalities		All	Fatal
1982	16	4	234	6,697,770	0.224	0.045	2	1	1	342,555	0.584	0.292
1983	22	4	15	6,914,969	0.318	0.058	1	0	0	383,830	0.261	-
1984	13	1	4	7,736,037	0.168	0.013	3	0	0	429,087	0.699	-
1985	17	4	197	8,265,332	0.206	0.048	4	3	329	444,562	0.900	0.675
1986	21	2	5	9,495,158	0.211	0.011	3	1	3	480,946	0.624	0.208
1987	32	4	231	10,115,407	0.306	0.030	2	1	1	529,785	0.378	0.189
1988	29	3	285	10,521,052	0.266	0.019	1	0	0	619,496	0.161	-
1989	24	8	131	10,597,922	0.226	0.075	4	3	147	676,621	0.591	0.443
1990	22	6	39	11,524,726	0.191	0.052	2	0	0	625,390	0.320	-
1991	25	4	62	11,139,166	0.224	0.036	1	0	0	641,444	0.156	-
1992	16	4	33	11,732,026	0.136	0.034	2	0	0	627,689	0.319	-
1993	22	1	1	11,981,347	0.184	0.008	1	0	0	724,859	0.138	-
1994	19	4	239	12,292,356	0.146	0.033	4	0	0	831,959	0.481	-
1995	34	2	166	12,776,679	0.266	0.016	2	1	2	728,578	0.275	0.137
1996	32	3	342	12,971,676	0.247	0.023	5	2	38	774,436	0.646	0.258
1997	44	3	3	15,061,662	0.292	0.020	5	1	5	776,447	0.644	0.129
1998	43	1	1	15,921,102	0.270	0.006	7	0	0	892,333	0.784	-
1999	47	2	12	16,693,365	0.282	0.012	5	0	0	861,843	0.580	-
2000	51	3	92	17,474,405	0.292	0.017	6	0	0	820,738	0.731	-
2001	36	6	531	15,998,000	0.200	0.013	4	0	0	732,700	0.546	-

NOTE: Effective March 20, 1997, aircraft with 10 or more seats must conduct scheduled passenger operations under part 121.

Source: www.ntsb.gov/aviation/Table6.htm

Source: www.ntsb.gov/aviation/Table7.htm

Figure 2-16: U.S. Air Carriers Operating Under Part 121 (Airlines)—Accidents, Fatalities and Rates, 1982 through 2001

- General aviation and helicopters fly to more than 20,000 landing facilities, while the airlines serve only about 700 well-lit airline-served airports.
- Many operations, such as EMS, aerial application, and law enforcement, have special mission-related risks.
- There are more takeoffs and landings per hour, generally the highest risk phases for general aviation and many helicopter operations.

Figure 2-17 shows that the accident rate for HEMS was dramatically higher than for all other aviation operations during the early and mid-1980s. Beginning in 1987, we see a sharp decline in the HEMS accident rate, which has remained consistently below the accident rates for both general aviation and all

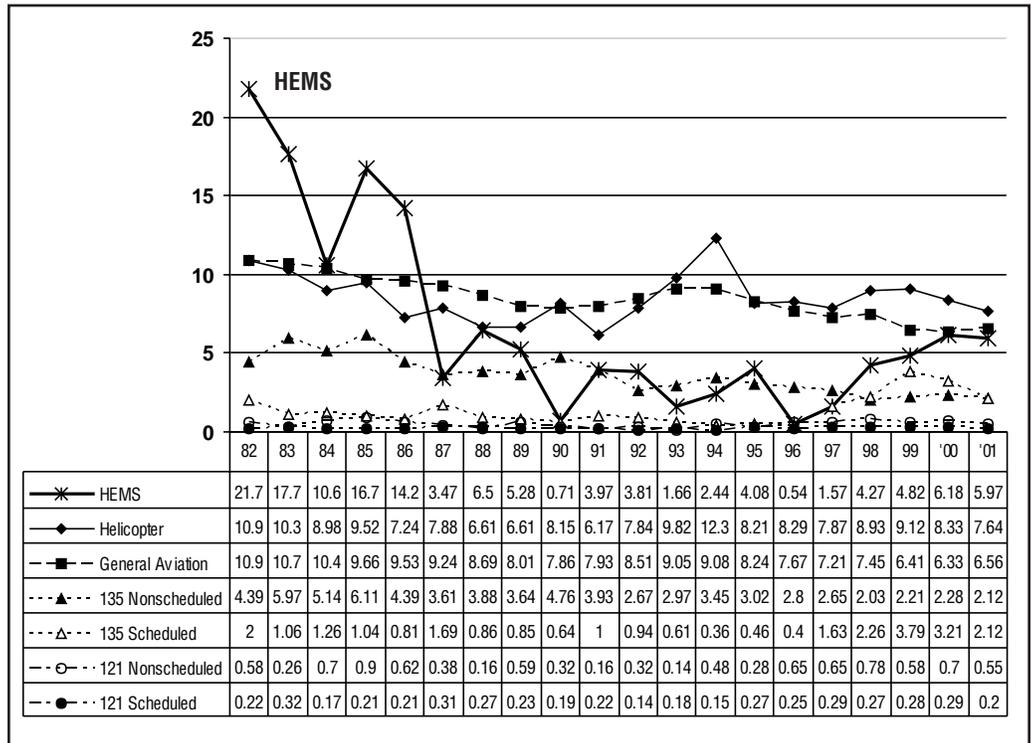


Figure 2-17: Accidents per 100,000 Flight Hours

helicopter aviation. In addition, from 1987 through 1997, the HEMS accident rate was lower than the overall accident rate for all Part 135 non-scheduled flights 6 of the 10 years. Since 1998, however, the HEMS accident rate has surpassed that of the non-scheduled Part 135 operations each year.

The data in Figure 2-18 represents the average accident rate for the past 20 years (1982-1999), 10 years, and 5 years for the five types of aviation operations, helicopters, and HEMS. Even with the high accident rates of the 1980s, the 20-year average for HEMS is below all helicopter operations and general aviation. For the 10-year average, the HEMS accident rate is less than 50% the rate of all helicopters and general aviation. For the past 5 years, the average accident rate for HEMS has gone up, but remains significantly lower than all helicopter operations and general aviation.

Figure 2-19 compares the fatal accidents per 100,000 flight hours for the various aviation operations. The results are similar to the total accident rates. Initially, the fatality rate for air medical helicopters was equal to or dramatically higher than all other aviation operations. In 1990, however, there were no fatal HEMS accidents. Then from 1992 to 1997, HEMS was consistently below both general aviation and all helicopter operations in fatal accidents. Since 1998, the HEMS fatality rate has been consistently higher.

The average fatal accident rate for the past 20 years, 10 years, and 5 years for the various aviation operations is seen in Figure 2-20. The 20-year average shows HEMS with a high fatal accident rate compared to all other aviation. However, the past 10 years has seen an improvement in the HEMS rate. For the 10-year average, HEMS has had a lower fatality rate than helicopters and general aviation (Part 91). For the past 5 years, however, the average HEMS fatality rate once again exceeds all other aviation operations.

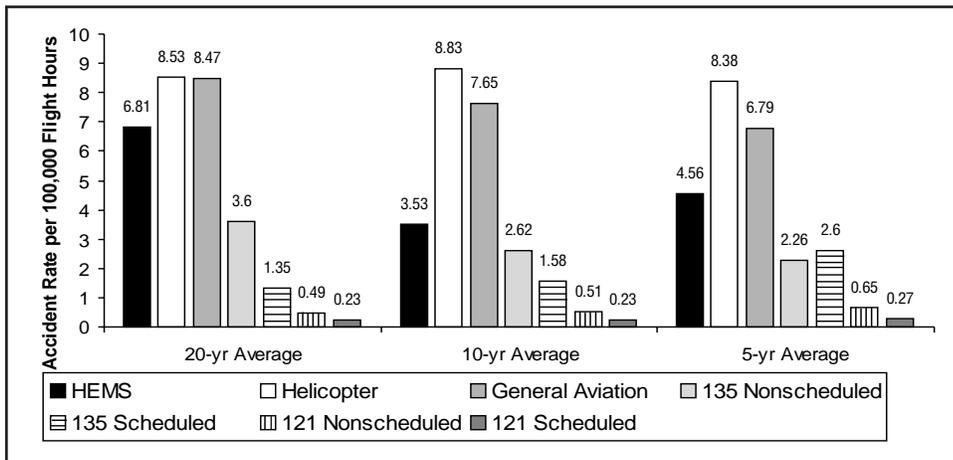


Figure 2-18: Average Accident Rates for Aviation Operations

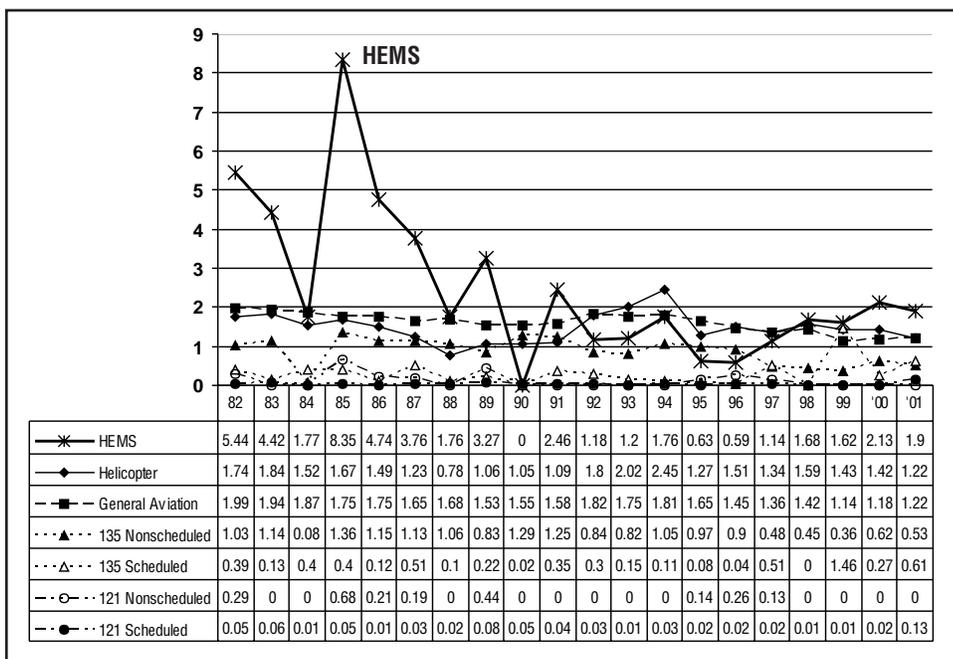


Figure 2-19: Fatal Accidents per 100,000 Flight Hours

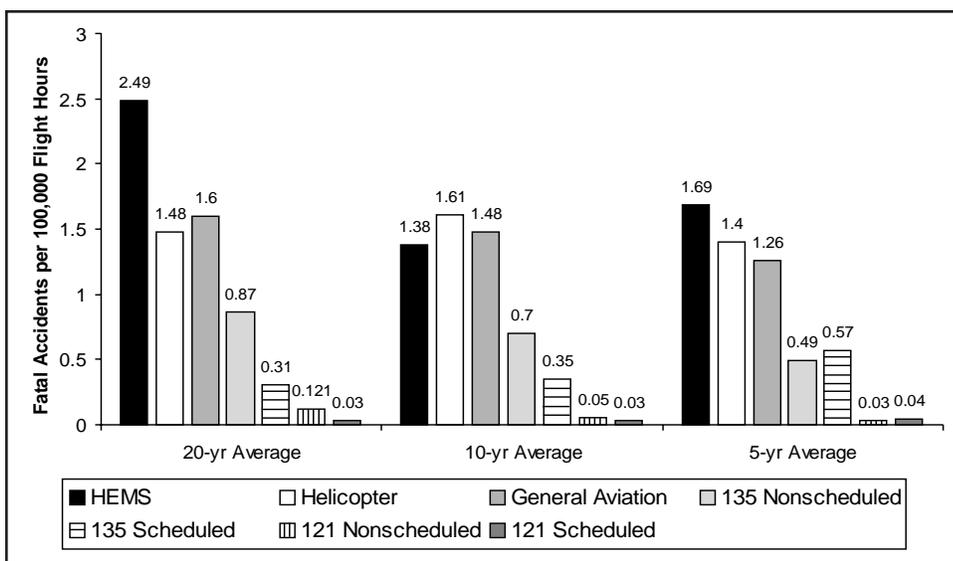


Figure 2-20: Average Fatal Accident Rates for Aviation Operations

U.S. Army Helicopter Accidents

In comparing HEMS to other aviation operations, we have not included any form of military aviation. However, much of the research regarding helicopter crashes and survivability has come from U.S. Army studies. It would seem a natural extension of our own study to compare Army accident rates with HEMS.

Information was obtained from the U.S. Army Safety Center at Fort Rucker, Alabama. From 1982–2000, U.S. Army helicopters flew an estimated 22.8 million flight hours worldwide, ranging from a high of 1.55 million hours in 1988 to a low of 753,000 hours in 1998. Total accidents that do not include any combat losses and accidents rates for nine different Army helicopters were also provided. Of these nine types of aircraft, the Army uses two models for medical missions—the UH-1 (“Huey”) and the UH-60 (“Blackhawk”). Additional accident information was provided on these two aircraft for 1992–2000, for both the medical (UH1-V and UH-60 MEDEVAC) and non-medical (UH1-AC and UH-60) versions.

During the 18-year period, the U.S. Army recorded a total of 707 Class A and Class B non-combat helicopter accidents. Between 1992–2000, there were a total of 212 accidents. Looking only at the UH-1 and UH-60 from 1992–2000, there were 77 Class A and Class B accidents—11 in MEDEVAC aircraft and 66 in non-medical helicopters. There were an additional 253 Class C accidents reported for the UH-1 and UH-60 helicopters during these 9 years. A total of 44 involved medical helicopters and 209 were non-medical aircraft.

It should be noted that the U.S. Army Accident Classification is very different than the NTSB definitions of accidents and incidents. Clearly, Class A and B would qualify as accidents under the NTSB definitions. Class C however, seems to cross the line between the NTSB definitions of accident and incident.

Unfortunately, our analysis of the Army accident data is limited by several factors. For 1982–2000, we have total flight hours, the number of accidents and the accident rate for the nine aircraft—but only for Class A and B accidents. For the UH-1 and UH-60, we have raw numbers of accidents for all three classes and for the mede-

Army Accident Classification	
Class A.	Damage costs of \$1,000,000 or more and/or destruction of an Army aircraft, missile or spacecraft and/or fatality or permanent total disability.
Class B.	Damage costs of \$200,000 or more, but less than \$1,000,000 and/or permanent partial disability and/or five (three as of 2002) or more people are hospitalized as inpatients.
Class C.	Damage costs of \$10,000 (\$20,000 as of 2002) or more, but less than \$200,000 and/or non-fatal injury resulting in loss of time from work beyond day/shift when injury occurred and/or non-fatal illness/disability causes loss of time from work.

Adapted from: http://asmis.army.mil/stats/pkg_definitions.class

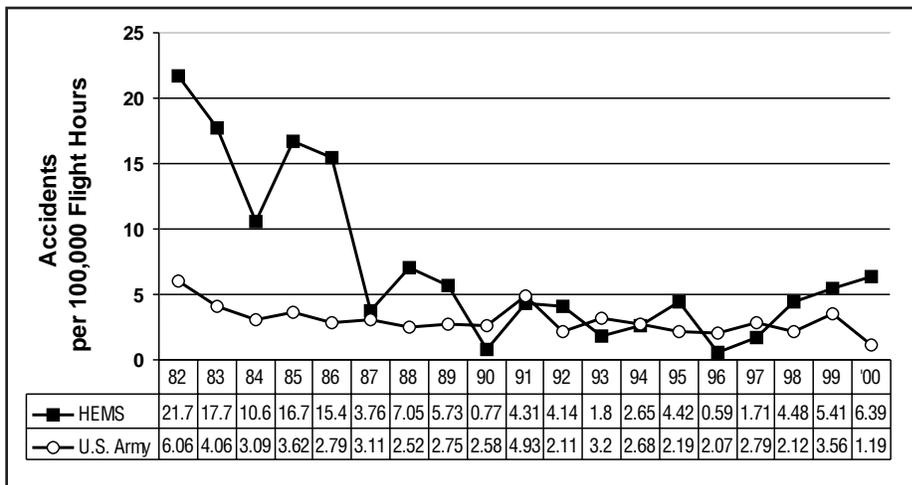


Figure 2–21: U.S. Army Helicopter Class A and B Accidents vs. HEMS, 1992–2000 (n=77) Adapted from: U.S. Army Safety Center, Fort Rucker, Alabama

vac vs. non-medevac aircraft. However, we lack the corresponding breakdown of flight hours for the medical flights compared to the non-medical flights. Knowing the specific medevac flight hours would have allowed a more meaningful comparison. Finally, we do not have any fatal accident numbers.

Knowing the limitations of our comparison, we have plotted the combined Class A and Class B accident rates along with the HEMS accident rates in Figure 2–21. Over this 19-year period, the Army accident rate was as high as 6.06 accidents per 100,000 flight hours in 1982 and as low as 1.19 in 2000. In the '80s, the HEMS accident rate was consistently higher than the Class A+B accident rate. From 1990–1997, the rates are very similar and since 1998 the HEMS rates have again been higher.

While we do not know the specific accident rates for the Army medevac helicopters, we do know that from 1992–2000, there were six non-medical accidents for every one medevac crash

involving the Huey and Blackhawk helicopters. However, if we were to also factor in the Class C accidents, our raw accident numbers would be increased more than four-fold.

Of interest, it should be noted that U.S. Army MEDEVAC missions are always 2-pilot operations. Most flights are “scene” flights and night missions, which account for an estimated half of all medical missions and are aided by night vision goggles (NVG).

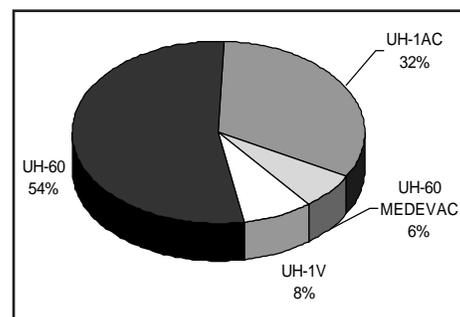


Figure 2–22: UH–60 vs. UH–1 Accidents 1992–2000 (n=77) Adapted from: U.S. Army Safety Center, Fort Rucker, Alabama

U.S. Forest Service Aviation Accidents

While the HEMS fatal accident rate has been higher than that of all other types of aviation for the past several years, it is not the most hazardous flying in the United States.

In August 2002, the *NBC Nightly News* reported that piloting Forest Service airtankers was the most dangerous flying in the United States. Since 1950, a total of 156 pilots had lost their lives fighting fires. NBC reported that the accident rate for Forest Service airtankers was found to be 13 per 100,000 hours of flight time. In comparison, they reported that the accident rate of U.S. military combat flight was 11 per 100,000 flight hours while that of civilian aviation was 3.6 per 100,000 flight hours.

Our own research into the Forest Service accident rates found that the reported accident rate of 13 per 100,000 hours of flight time represents a 10-year average for airtankers from 1992 to 2001. During that time, the annual range was from 0 to 51.36. During that same timeframe, other fixed-wing aircraft (not airtankers) had an average accident rate of 2.70 (range 0 to 15.13) and helicopters had an average of 8.93 (range 0 to 24.55). The 10-year average for all Forest Service aviation was 5.78 accidents per 100,000 flight hours, with a range of 1.58 to 11.67.

Figure 2–23 shows the annual accident rates and fatal accident rates for the four different Forest Service aviation operations compared to HEMS. Figure 2–24 plots the 5-year and 10-year averages for these operations.

Within this 10-year period, HEMS had the highest accident rates and highest fatal accidents in 1999 and 2001. In addition, in 1996, when HEMS had its second lowest fatal accident rate, the U.S. Forest Service had a rate of zero. As the 5-year and 10-year averages indicate, HEMS is well below the accident rates for helicopters and airtankers used under contract by the U.S. Forest Service, but remains above the rates for fixed-wing aircraft.

	'92	'93	'94	'95	'96	'97	'98	'99	'00	'01	5-yr Avg.	10-yr Avg.
Accident rate per 100,000 flight hours												
HEMS	3.81	1.66	2.44	4.08	0.54	1.57	4.27	4.82	6.18	5.97	4.56	3.53
USFS Owned	0	0	6.94	10.11	8.58	0	0	0	7.84	0	1.57	3.35
Fixed-wing	0	15.13	2.22	0	0	0	3.08	0	2.85	3.76	1.94	2.70
Airtanker	19.42	51.36	9.9	24.07	0	0	27.13	0	0	0	5.43	13.19
Helicopter	14.29	8.31	14.22	0	11.01	24.54	4.09	3.97	3.76	5.06	8.28	8.93
Fatal Accident rate per 100,000 flight hours												
HEMS	1.18	1.2	1.76	0.63	0.59	1.14	1.68	1.62	2.13	1.9	1.69	1.38
USFS Owned	0	0	0	10.11	0	0	0	0	0	0	0.00	1.01
Fixed-wing	0	5.04	0	0	0	0	0	0	2.85	0	0.57	0.79
Airtanker	19.42	51.36	9.9	24.07	0	0	27.13	0	0	0	5.43	13.19
Helicopter	0	0	6.09	0	0	6.13	4.09	0	0	0	2.04	1.63

Figure 2–23: Accident Rates for U.S. Forest Service Aviation Operations vs. HEMS, 1992–2001

Adapted from: U.S. Department of Agriculture, Forest Service, <http://www.aviation.fs.fed.us/library/fy01avsumm.pdf>

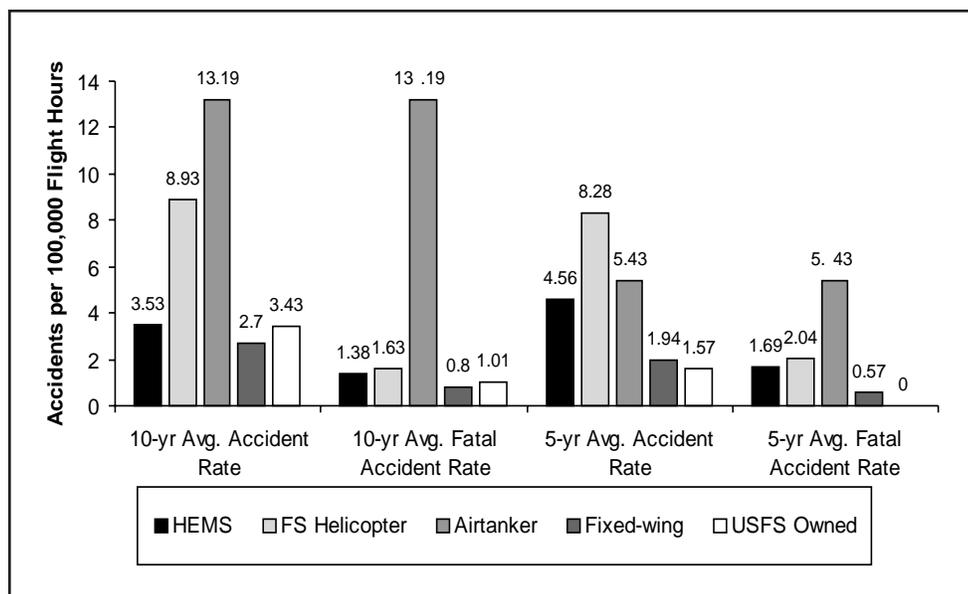


Figure 2–24: U.S. Forest Service Aviation Accidents vs. HEMS, 1992–2001

Adapted from: U.S. Department of Agriculture, Forest Service, <http://www.aviation.fs.fed.us/library/fy01avsumm.pdf>

SINGLE- VS. TWIN-ENGINE HELICOPTER ACCIDENT RATES

Since 1990, HAI has tracked the accident rate for single-engine vs. multi-engine helicopters, as well as the total helicopter flight hours. In general, it appears that single-engine flight hours have been approximately 3 times that of multi-engine flight hours each year. A dramatic differ-

ence is seen in the accident rate per 100,000 flight hours when comparing single- vs. twin-engine helicopters. The fatal accident rate however demonstrates less disparity. In fact, a 1999 study by the Flight Safety Foundation found the fatal accident rate of single- and twin-engine helicopters to be similar. Figure 2–25 charts the total accident and fatal accident rates for single- and multi-engine helicopters.

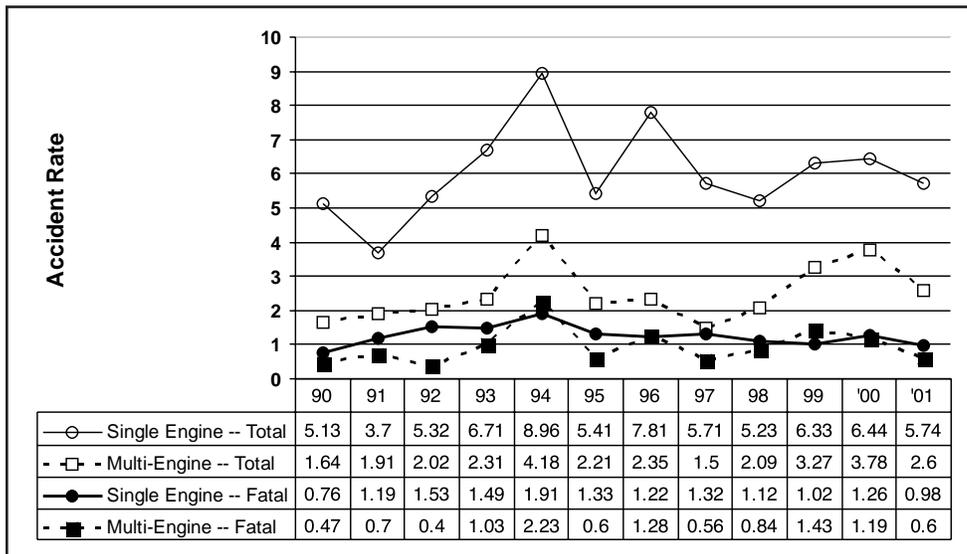


Figure 2-25: Total Accidents and Fatal Accidents per 100,000 Flight Hours Single- vs. Multi-Engine Helicopters, 1990-2001

Adapted from: Helicopter Association International, <http://www.rotor.com/safety/stats70.01.xls>

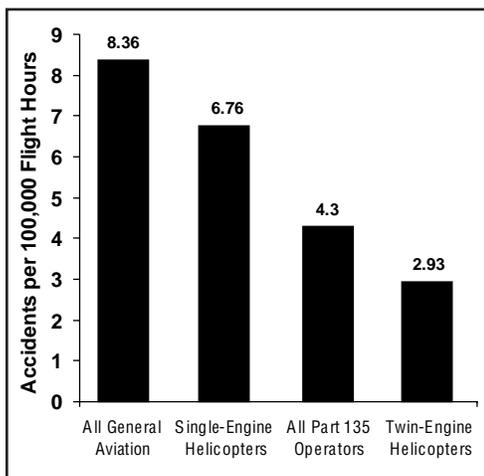


Figure 2-26: Accident Rate Comparison, 1993-1997

Adapted from: Harris, *Helicopter Safety*, Jan/Feb 1999

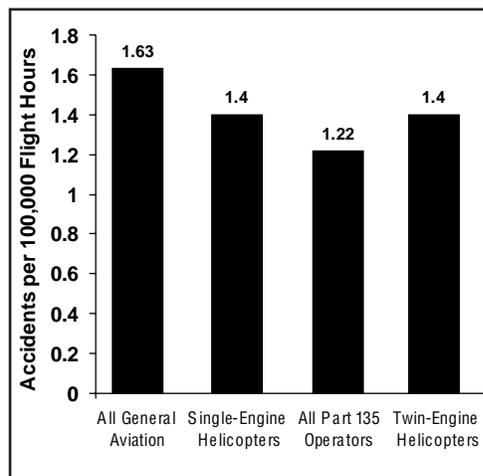


Figure 2-27: Fatal Accident Rate Comparison, 1993-1997

Adapted from: Harris, *Helicopter Safety*, Jan/Feb 1999

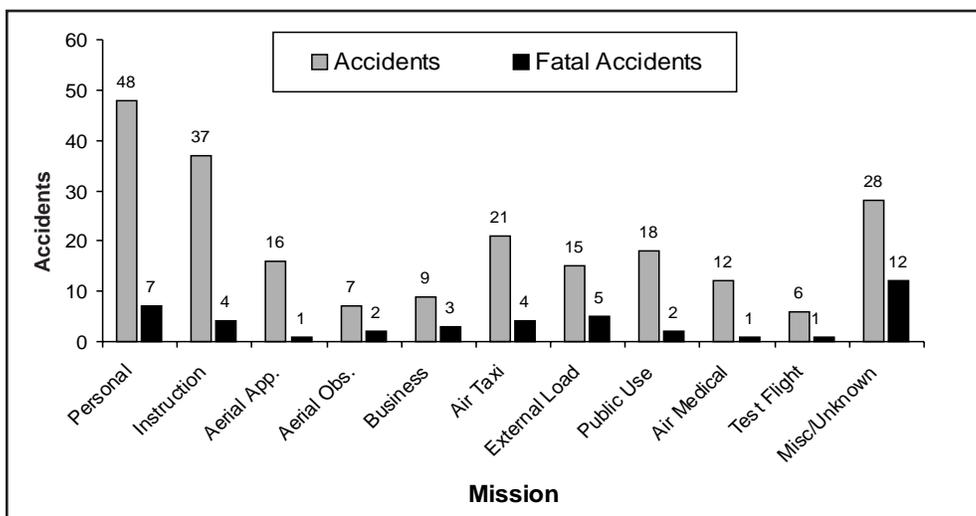


Figure 2-28: Helicopter Accident Statistics, 2001

Adapted from: <http://safecooper.arc.nasa.gov/>

The Flight Safety Foundation study looked at turbine-engine helicopter accidents and compared them with all Part 135 operations and with general aviation. Figure 2-26 shows that the twin-engine helicopter accident rate was lower than the accident rates of general aviation aircraft, single-engine helicopters, and all Part 135 operations.

Nearly half (48%) of the twin-engine helicopter accidents were fatal. From 1993-1997, twin-engine helicopters were involved in 23 fatal accidents, or 1.4 fatal accidents per 100,000 flight hours. Figure 2-27 compares the fatal accident rates for helicopters (single- and twin-engine) general aviation, and air taxis.

HELICOPTER ACCIDENTS, 2001

Year 2001 saw a 12% increase compared to 2000 when looking at all helicopter accidents. During the year, there were 217 helicopter accidents (see Figure 2-28), 42 of which were fatal, killing 105 people. Piston-engine helicopters accounted for 108 accidents, of which 19 were fatal. There were 95 single-turbine accidents (20 fatal) and 13 twin-turbine accidents (3 fatal). Of interest, this NASA "Safecooper" website lists only one of 12 air medical helicopter accidents as fatal.

SECTION 3: A COMPARISON OF RISK

Nothing is completely safe. Everything we do has some type of risk and these risks can never be totally eliminated from any situation. The issue is not one of avoiding risks all together, but rather one of managing risk in a sensible manner.

A 1999 *Time* magazine article, "Life on the Edge," states that "America has embarked on a national orgy of thrill seeking and risk taking." The article focused on the rise of extreme sports like BASE jump-

ing, snowboarding, ice climbing, skateboarding, and paragliding but mentioned other risky activities—and occupations—as well. The article pointed out that Americans were taking greater risks than ever before in many areas. More than 30% of U.S. households owned stocks of some form or another, which was up from 12% just 10 years before. Social behavior had also become more risky, with unprotected sex on the upswing and illicit drugs like heroin on the increase. Finally, the article pointed out that many people assumed various risks in their chosen careers. From the MBAs who were trying to strike it rich in the “dot-com” world; to the 14.5% who voluntarily had left their jobs (highest in a decade) for new opportunities; to the options trader, neurosurgeon, fire fighter, and race car driver—all had chosen to assume a varying degree of occupational risk.

For all of these thrill seekers and risk takers, risk management requires a minimum of common sense and information about the character and magnitude of the risk taken. We must inform ourselves or be educated about the relevant risks and then act accordingly. Where you choose to live, your occupation, chosen modes of travel, recreational activities, or just staying at home—all have risks of accidents, injury, and death.

Determining Risk

Statistics on accidents, injuries, and fatalities are kept for nearly every activity and occupation. With raw data available, we need to be able to calculate the magnitude of a risk. This is especially important if we hope to compare different types of activities. In order to assess and compare risk, the relevant figure needed must be in the form of a ratio, fraction, or percentage. To arrive at these figures—to normalize the data—we need to know two numbers. The numerator of the fraction tells us how many individuals doing a particular activity were either injured or killed over a given period of time. The denominator represents how many people were engaged in that activity—the population at risk. By reducing all risks to ratios in this way we can begin to compare different types of activities and the relative risks. The larger the ratio, the riskier the activity.

There are two other options to normalize this data which are used more commonly by the National Safety Council (NSC). The first is to take the above fraction and normalize it to “1 in X,” as in “the odds of something is 1 in X.” The other option is to calculate death rates and injury rates per 100,000 persons.

There is risk of injury and death every hour of every day. The NSC estimates that while you make a 10-minute safety presentation, two persons will be the victims of unintentional deaths and approximately 370 will suffer a disabling injury. On the average, there are 12 unintentional-injury deaths and about 2,400 disabling injuries every hour during the year. Figure 3–1 shows a breakdown of the frequency and death rate of the major classifications of accidental deaths and injuries in the United States for 2000.

An individual is nearly twice as likely to be injured at work than in his/her car. Staying at home or going out in public is even worse. You are more than three times more likely to be injured at home or in public than in your car. However, in general, you are six times more likely to die in your car than die due to an accident at work and nearly one-and-a-half times more likely to suffer a fatal injury in your car than at home.

Where you choose to live will also impact your likelihood of dying from an unintentional injury. According to NSC statistics, Massachusetts and Rhode Island boast the lowest accidental death rates among the fifty states. However, if you live in New Mexico, Wyoming, or Alaska (the states with the highest accidental death rate), your chances of an unintentional death are 2.5 to nearly 3 times higher.

HEMS: ANALYZING THE POPULATION AT RISK

With injury and death statistics available for various occupations and types of activities, it would be necessary to determine the size of the “population at risk” in HEMS. To accomplish this—and with no such data available—we must make several assumptions and do various calculations.

Methodology

If one were to try to compare air medical transport to other occupations or “routine” risks to determine either the odds of death in one year or the fatality rate per 100,000 we would need to know two things. The first is the number of HEMS crew fatalities per year. The second would be the number of people engaged in HEMS transport (i.e., the number of HEMS pilots and medical crewmembers) for each year. The number of fatalities is known, but the number of crewmembers in HEMS has never been tracked or even estimated in the literature.

For the purpose of this study, we begin by estimating the average number of crewmembers per helicopter. We can assume that the typical flight crew for each dedicated medical helicopter includes 4 pilots, 6–8 nurses as the primary caregivers, and 10–12 second medical crewmembers (often paramedics, physicians, nurses, respiratory therapists, etc., who fly full- or part-time). Therefore, the average dedicated medical helicopter would have 20 to 24 crewmembers. For the purpose of our calculations, we will use an average of 22 persons.

Class	Severity	One every	2000 Total	Death Rate
All Unintentional	Deaths	5 minutes	97,300	35.3
	Injuries	1.5 seconds	20,500,000	
Motor-Vehicle	Deaths	12 minutes	43,000	15.6
	Injuries	14 seconds	2,300,000	
Work	Deaths	102 minutes	5,200	1.9
	Injuries	7 seconds	3,900,000	
Home	Deaths	18 minutes	29,500	10.7
	Injuries	4 seconds	7,100,000	
Public (nonmotor-vehicle)	Deaths	24minutes	22,000	8.0
	Injuries	4 seconds	7,300,000	

Figure 3–1: Unintentional Deaths and Injuries, 2000

Adapted from: National Safety Council, <http://nsc.org/library/rept2000.htm>

A review of the air medical literature showed there was no documentation as to the number of dedicated EMS helicopters from 1981 to 1991. Our Internet *Flightweb* survey provided us with a fairly accurate number of dedicated helicopters as well as HEMS programs for the year 2000. Assuming a steady annual increase in the number of aircraft between 1991 and 2000, we are able to predict the number of helicopters dedicated to the HEMS mission for each year. For 2001, we factored in the percent increase as determined from our operator and manufacturer survey.

We now have the necessary information to determine the approximate size of the population at risk. In 2001, there were an estimated 400 dedicated medical helicopters. Multiplying this figure by 22 crewmembers, we can estimate that the population at risk is approximately 8,792. Using this figure and knowing the number of crewmember deaths attributed to HEMS accidents, we are now able to compare some annual statistics in a more meaningful manner. In addition, we will be able to compare HEMS risk with other occupations and activities.

It is important to realize that in estimating exposure in this method, we are doing so for the *average* crewmember and the *average* flight program. The National Safety Council points out that predicting the rate for potential injury or death is strongly dependent upon the length of exposure to a particular activity for the specific population at risk. This would be similar to comparing the potential exposure rate for full-time vs. part-time

HEMS personnel; four pilots vs. 6–8 nurses; programs that fly once a day vs. those that fly several times a day; programs that fly short distances to those that fly much further, and so on. When we normalize the raw data, it does not take into account the *amount* of exposure for an individual during the year. For this study, we are basing our calculations on the average program, which in 2001 transported approximately 882 patients, flying an estimated 957 hours over the course of the full year, and all crewmembers (pilots and medical crewmembers) flying an equal amount of time.

Results

Fatality statistics for HEMS personnel are presented in four different formats. In each case, the number of crew fatalities was determined for each year. From the total 171 HEMS fatalities, 21 patient

fatalities, 7 dual-purpose aircraft crewmember fatalities and 6 other fatalities were removed from the appropriate years leaving only dedicated HEMS crew fatalities for our comparison. Figure 3–2 depicts the number of HEMS personnel who have died each year since 1980. The fatalities for 2002 (as of September 30, 2002) are included in this graph but are not included in any of our calculations. As the graph clearly shows, 2002 has had more crew fatalities than any year in HEMS history. Figure 3–3 shows the various calculations and the results used to determine the fatality rates.

The National Safety Council routinely normalizes fatality data to a death rate per 100,000 population at risk in a given year. Over the 21 years reviewed for this portion of the study (1981–2001), the HEMS population has grown from approximately 858 to 8,792. While this growth seems impressive, this is still a

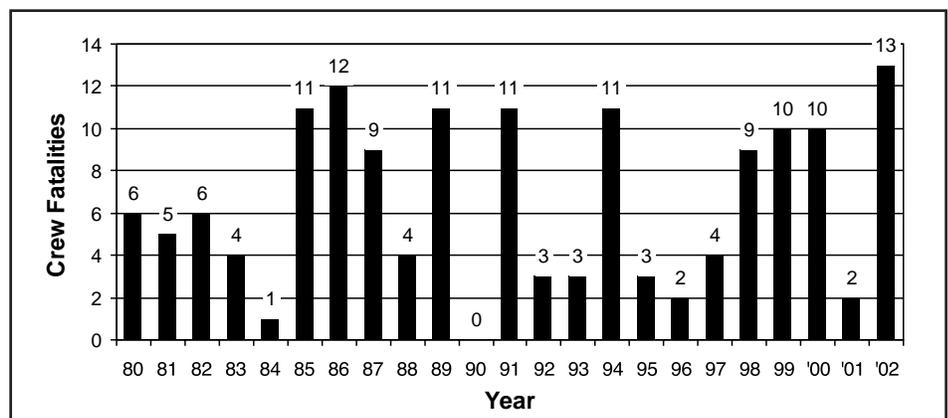


Figure 3–2: HEMS Crew Fatalities per Year, 1980–2002* (as of September 30, 2002)

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	Totals
1 # of Helicopters	39	45	62	75	91	119	151	184	195	213	231	225	242	259	276	293	309	326	343	360	377	400	
2 Calc. Total Crew	858	990	1364	1650	2002	2618	3322	4048	4290	4686	5082	4950	5322	5693	6065	6436	6808	7179	7551	7922	8294	8792	185064
3a Crew Fatalities	6	5	6	4	1	11	12	9	4	11	0	11	3	3	11	3	2	4	9	10	10	2	137
3b Dual-Purpose Crew Fatalities										2		2							3				7
4 Patient Fatalities	1	1	1	0	1	1	1	1	1	3	0	3	0	2	0	0	1	1	2	0	1	0	21
5 Other Fatalities								2				1											6
6 Total Fatalities	7	6	7	4	2	12	13	12	5	16	0	17	3	5	11	3	3	5	14	10	11	5	171
7 Crew Fatality Rate	0.70%	0.51%	0.44%	0.24%	0.05%	0.42%	0.36%	0.22%	0.09%	0.23%	0.00%	0.22%	0.06%	0.05%	0.18%	0.05%	0.03%	0.06%	0.12%	0.13%	0.12%	0.02%	0.196%
8 1 in _____	143	198	227	413	2002	238	277	450	1073	426	N/A	450	1774	1898	551	2145	3404	1795	839	792	829	4396	1158
9 per 100,000	699	505	440	242	50	420	361	222	93	235	0	222	56	53	181	47	29	56	119	126	121	23	196
10 No Injuries	2	6	17	9	8	11	19	0	15	8	4	9	4	0	4	13	0	5	12	18	13	18	195
11 Injuries Serious	0	0	0	3	3	5	3	0	5	4	0	0	10	3	1	0	0	0	5	6	0	8	56
12 Minor	0	3	0	3	8	11	10	1	6	3	0	0	4	3	3	5	0	1	0	0	7	5	73
13 Total Injuries	0	3	0	6	11	16	13	1	11	7	0	0	14	6	4	5	0	1	5	6	7	13	129
14 Injury Rate	0.0%	0.30%	0.00%	0.36%	0.55%	0.61%	0.39%	0.02%	0.26%	0.15%	0.00%	0.00%	0.26%	0.11%	0.07%	0.08%	0.00%	0.01%	0.07%	0.08%	0.08%	0.15%	0.16%

Figure 3–3: Fatalities and Fatality Rates

very small sampling to translate to a ratio per 100,000. As Figure 3-4 shows, with such a small population base, each fatality has a significant impact on the fatality rate. In this format, the range for the fatality rate is from 0 to 699 per 100,000. With such a wide range, a 22-year average is calculated that will be used when we compare HEMS to other risks. The average annual death rate over the 22 years is 196 per 100,000 crewmembers.

Another way to look at the relative risk of HEMS transport is in the form of a ratio—dividing the number of fatalities by the number of crewmembers for each year. Since this uses the same data, but in a slightly different equation, the graph would look essentially the same as Figure 3-4. For this annual comparison (Figure 3-3, Line 7) the range is from 0.00% to 0.70%, with a 22-year average of 0.196%. The higher the percentage, the greater the apparent risk in that particular year.

The final relationship that is used to compare the annual number of HEMS crew fatalities is in terms of “odds.” For example, in 2001 there were only two crew deaths out of an estimated crew population of 8,792. Looking solely at the numbers, the odds to an individual crewmember suffering a fatal accident that year would be considered to be 1 in 4,396. Contrasting this with what could be considered our riskiest year (1980), there were 6 crew fatalities out of an estimated 858 crewmembers industry-wide. This would correspond to fatality odds of 1 in 143. Excluding 1990 when there were no fatalities, the average odds per year over the 22-year period are 1 in 1,158. Figure 3-5 illustrates the odds of a fatality over the study time period.

COMPARING HEMS TO OTHER RISKS

To further illustrate the risk related to HEMS transport, we can compare and contrast the above numbers with other activities, other types of accidents, and other causes of death. Taking into consideration the wide range of fatality rates and odds that we have estimated for each year in HEMS, the calculated *averages* will be used in subsequent comparisons.

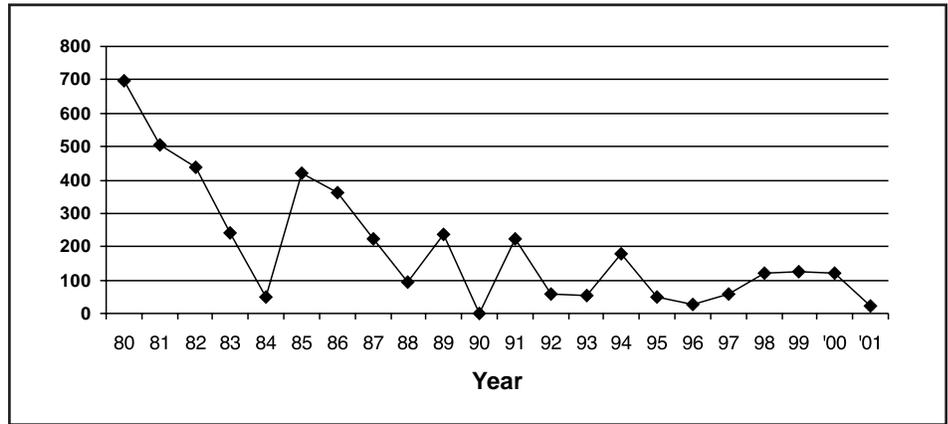


Figure 3-4: HEMS Fatality Rate per 100,000 Personnel, 1980–2001

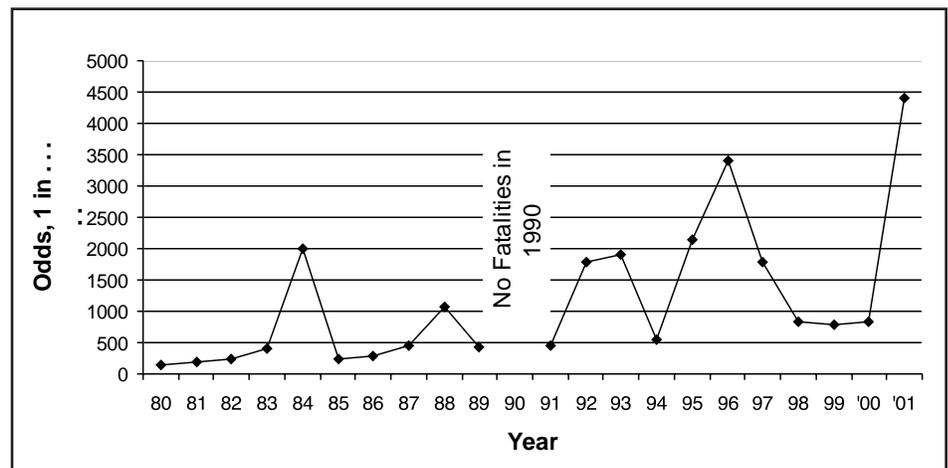


Figure 3-5: Odds of a Fatality for HEMS Personnel, 1981–2001

Cause of Death – An Overview

Since 1921, the National Safety Council has been a source of accurate, comprehensive, and objective statistics on unintentional injuries, their costs, trends, and other characteristics. Accidents and unintentional injuries generally rank as the fifth leading cause of death worldwide behind heart disease, cancer, stroke, and COPD.

The NSC provides statistics looking at the total number of deaths and the relative death rate for various unintentional deaths per 100,000 population. The leading five causes of fatal unintentional injuries (motor vehicle accidents, falls, poisoning, drowning and choking) have been the same from 1970 through 1998 (1998 is the last year this data was available). Together, these five categories of

injury accounted for nearly 80% of all accidental deaths (77,951 of the 97,835) in 1998. Figure 3-6 identifies the leading causes of accidental death, number of deaths, and death rate for 1998. In addition, we have included data on other causes of death (heart disease, cancer, and stroke) as well as a comparison to HEMS.

As you can see the 22-year average fatality rate for HEMS is very high. When you consider the average annual death rate over the 22 years reviewed, HEMS is surpassed only by heart disease and cancer when the data is normalized per 100,000 persons.

What are the Odds...

The NSC reports that motor-vehicle accidents cause more accidental deaths in the United States than any other unintentional injury. Looking at the

Cause of Death (in rank order)	Deaths, 1998	Death Rate Per 100,000
All Causes, all ages	2,337,256	864.9
Heart Disease	724,859	268.2
Cancer	541,532	200.4
HEMS (range over a 22 year period: 0–699 per 100,000)		
Stroke	158,448	58.6
Chronic obstructive pulmonary diseases (COPD)	112,584	41.7
All Accidental Deaths	97,835	36.2
<i>(Following is a select listing of accidental deaths)</i>		
Transport Accidents	45,774	16.9
Motor-vehicle	43,501	16.1
Air and space transport	692	0.3
Water transport	692	0.3
Railway	515	0.2
Misc.	374	0.1
Falls	16,274	6.0
Poisoning by solids, liquids, gases, vapors	10,255	3.8
Drugs, medications, and biologicals	9,838	3.6
Drowning	3,964	1.5
Choking, Inhalation, ingestion of food or other object	3,515	1.3
Fire and flames	3,255	1.2
Complications/misadventures of surgery/medical care	3,228	1.2
Natural and environmental factors	1,521	0.6
Firearm, missile	866	0.3

Figure 3–6: Leading Causes of Death, 1998
Adapted in part from: National Safety Council, Injury Facts 2001 Edition

Type of Accident or Manner of Injury	Deaths, 1998	One-year odds	Life-time Odds
HEMS Accidents (22-year average)		1,158	
Total deaths due to injuries	150,445	1,796	23
All Accidental Deaths	97,835	2,762	36
Transport Accidents	45,774	5,904	77
Motor-vehicle	43,501	6,212	81
Railway	515	524,753	6,842
Other road vehicle	235	1,149,991	14,993
Water transport	692	390,532	5,092
Air and space transport	692	390,532	5,092
Poisoning by solids and liquids	10,255	26,353	344
Poisoning by gases and vapors	546	494,960	6,453
Complications, misadventures of surgical, medical care	3,228	83,720	1,092
Falls	16,274	16,606	217
Fire and flames	3,255	83,025	1,082
Natural and environmental factors	1,521	177,678	2,317
Excessive heat	375	720,661	9,396
Excessive cold	420	643,448	8,389
Lightning	63	4,289,651	55,928
Cataclysmic storms, and floods	204	1,324,745	17,272
Drowning, submersion	3,964	68,176	889
Inhalation and ingestion of food	1,147	235,613	3,072
Inhalation and ingestion of other object	2,368	114,125	1,488
Mechanical suffocation	1,070	252,568	3,293
Struck by falling object	723	373,787	4,873
Machinery	1,018	265,470	3,461
Adverse effects of drugs in therapeutic use	276	979,159	12,766
Hanging, strangulation, and suffocation	5,726	47,197	615
Firearms	17,424	15,510	202

Figure 3–7: Odds of Death Due to Unintentional Injury, Selected Causes, 1998
("1 in _____")

Adapted in part from: National Safety Council, <http://nsc.org/lrs/statinfo/odds.htm>

odds, an annual risk of death of 1 in a million is equivalent to the risk of dying in a car accident if you travel in your car one mile a week for a full year. Driving (or riding) 10 miles per week in an auto increases your annual risk of dying in an MVA to 1 in 100,000. If you increase your weekly driving to 100 miles, your annual risk of death is now 1 in 10,000, while at 1,000 miles per week our odds of dying in a car accident is 1 in 1,000.

The NSC often fields questions about "odds." For example, "What are the odds of dying in a plane crash or being killed by lightning?" In response to questions like this, the NSC has determined the "Odds of Death Due to Injury" in the United States for various activities. For 1998 (the most recent year of these statistics) the one-year odds were calculated by dividing the 1998 population by the number of recorded deaths from specific injuries that year. To determine the lifetime odds, the NSC took the one-year odds and divided them by the life expectancy of a person born in 1998, which is 76.7 years. The NSC also published death and injury rates per 100,000 for various occupations, activities, and modes of travel.

For 1998, the NSC determined that the odds of dying from an injury (intentional or unintentional) during that year were 1 in 1,796. They also determined that the lifetime odds of dying from an injury for a person born in 1998 were 1 in 23. Looking only at accidental (unintentional) deaths in 1998, the odds decrease to 1 in 2,762 in that year and to 1 in 36 lifetime. Figure 3–7 shows the 1998 odds of death in the United States due to an unintentional injury for various causes. Included in the table are the average one-year odds for a HEMS crewmember to die in a fatal crash. As you can see, the odds of suffering a fatality in HEMS exceed that of motor-vehicle accidents and all other accidental deaths.

As previously discussed, one of the problems with data that is normalized in this fashion is that it does not take into account the true amount of exposure during the year. It assumes all exposures are equal. A more accurate approach would be to determine the exposure (time, etc.) that might result in a specified risk that can be compared to other activities.

We have determined that in HEMS there is an average one-year risk of death of 1 in 1,158. *The Book of Risks* has identified several activities that produce a 1-in-1,000 risk of death. In the 22-year HEMS study period an estimated 3,002,176 total hours have been flown. Adding together the estimated number of crewmembers each year yields a total of 105,922. This corresponds to an average exposure of 28.3 hours of flight time producing the estimated odds of 1-in-1,158. Adjusting the ratio to 1-in-1,000, we get an average exposure of 32.9 hours.

Activity	Time/Effort Involved
Rock climbing	25 hours
HEMS transport	32.9 hours
Skydiving	50 hours
Driving a motorcycle	55 hours
Skiing	340 hours
Flying on a scheduled airline	1,200 hours
Driving a car	52,000 miles

Figure 3–8: Activities Producing a 1-in-1,000 Risk of Death

Adapted in part from: Laudan, *The Book of Risks*, 1994.

HEMS: The Risk to the Patient

There is some level of risk related to all aspects of healthcare—every procedure performed, every medication dispensed, and every patient transported. The possibility of adverse events or medical errors represents a significant risk to each and every patient.

In *Human Error*, James Reason defines an error as “the failure of a planned action to be completed as intended (i.e., error of execution) or the use of a wrong plan to achieve an aim (i.e., error of planning).” An accident represents an adverse outcome after an error.

The results of the “1991 Harvard Medical Practice Study” concluded that 3.7% of New York hospitalizations resulted in adverse events, of which 13.6% led to death. A subsequent study published in 1999 found that in Utah and Colorado, 2.9% of the hospital admissions experienced an adverse event, with 6.9% of these resulting in a fatality.

According to the Institute of Medicine publication, with over 33.6 million admissions to U.S. hospitals in 1997, the results of these two studies would suggest that between 44,000 and 98,000 Americans die in hospitals each year as a result of medical errors.

To put these figures in perspective, this would be roughly equivalent to the crash of a jumbo jet carrying 500 passengers every 2–4 days. In addition, normalizing the data yields a death rate between 131 and 292 per 100,000 patients due to medical errors.

It is noted that the total number of deaths and corresponding death rate is significantly different than the statistics presented for “complication of surgery/medical care” that are listed in Figure 3–6. The National Safety Council death rate is based upon the reported number of deaths in this category compared to the entire U.S. population. The researchers of the two cited studies based their estimates upon a comprehensive review of a sampling of medical records for adverse events. The estimated number of deaths was then calculated for the number of annual *patients* (1997) rather than the entire population. According to the U.S. Department of Commerce, the population in the United States in January 1997 was 266,490,000 people. Normalizing the estimated number of deaths from the New York and Utah/Colorado studies for the entire U.S. population yields a death rate per 100,000 between 16.5 and 36.8 due to medical errors. This is still significantly higher than the NSC rate of 1.2.

While air medical *transport* is not a medical *treatment* and aviation accidents would not be considered a medical error, some could argue that these accidents

represent an adverse event in the health-care environment. In our 22-year study, we estimate that a total of 2,745,207 patients have been flown by HEMS. Over this same time period, 21 patients have lost their lives in HEMS accidents. This corresponds to a death rate of 0.76 per 100,000 patients flown. This takes into account only fatal injuries as a result of helicopter accidents and does not address any medical errors or other adverse events that could take place during transport. Based upon these figures, it would appear that there is a far greater risk to the patient of dying from an adverse event while hospitalized than from an accident aboard a medical helicopter.

Occupational Risks: Deaths and Injuries in the Workplace

In 2000, there were 5,200 workplace accidental fatalities, while an additional 3.9 million American workers suffered disabling injuries on the job. The NSC reports an average death rate across all industries at 3.8 per 100,000 workers, with mining and agriculture having the highest rates. Figure 3–9 shows that if HEMS “workers” were compared to the published NSC data, the average annual HEMS death rate is approximately nine times greater than the riskiest industries tracked by the NSC. However, it must be pointed out that this comparison is greatly distorted when you consider the small HEMS “population.” Even in 2001, with our largest estimated number of crewmembers, 2 fatalities resulted in a death rate of 23 per 100,000.

The picture changes dramatically if you look at the rate of injuries, not just

Industry	Workers	Deaths	Death Rate ¹	Disabling Injuries	Injury Rate
All industries	136,402,000	5,200	3.8	3,900,000	2.86%
HEMS (22 yr. Avg)			196		0.16%
Agriculture	3,380,000	780	22.5	130,000	3.85%
Mining, quarrying	520,000	110	21.2	20,000	3.85%
Construction	8,949,000	1,220	13.6	470,000	5.25%
Manufacturing	19,868,000	660	3.3	630,000	3.17%
Transportation and public utilities	8,084,000	930	11.5	380,000	4.70%
Trade	27,723,000	420	1.5	750,000	2.71%
Services	47,611,000	630	1.3	940,000	1.97%
Government	20,267,000	450	2.2	580,000	2.86%

Figure 3–9: U.S. Unintentional Work-Related Injuries and Deaths, 2000

¹Per 100,000 workers. Adapted in part from: National Safety Council, *Injury Facts 2001 Edition*

fatalities. The overall injury rate for all industries is 2.86%, ranging from 1.97% to 5.25% of the workers. Over the 22-year period, the injury rate for HEMS ranges from 0.0% to 0.61%, with an average of 0.16%. This injury rate takes into account only injuries that were suffered in helicopter accidents. It does not take into account any other etiology of disabling injury (e.g., back injury, falls) that could afflict an air medical crewmember while on duty.

A Pittsburgh study by Doyle et al., however looked at occupational injuries in air medical transport. Presented at the 2002 Critical Care Transport medicine Conference (CCTMC), this 3-year study found that the risk per flight of a crewmember sustaining a reportable injury is very low. A total of 16,062 flights resulted in only 86 injuries. However, Doyle also concluded that of the 140 flight personnel, 59% had sustained a reportable injury.

Although industries differ, the types of injuries that occur are common. Figure 3–10 shows the various mechanisms of injury and the percent seen in all industries. As this chart clearly shows, there are inherent risks to all occupations that could result in injuries or death. In many ways the risks to health care providers may be similar to other professions, but there may also be greater risk in certain areas. For HEMS personnel, flying is indeed one of those risks. Health care workers, including HEMS personnel, may be exposed to other risks as well.

Violence in the workplace is an all too common problem, with homicide being the leading cause of occupational death among all workers in the United States. It is estimated that 1,000 deaths in the workplace are due to assault each year. Unfortunately, health care workers are not immune to work-related attacks.

According to a 1998 OSHA Publication, more assaults occur in the health care and social services industries than in any other. They cited Bureau of Labor Statistics (BLS) data that showed health care and social service workers having the highest incidence of injuries due to assault. According to one study by Goodman et al., in 1994, between 1980 and 1990, 106 occupational violence-related deaths occurred among health care workers, including 27 pharmacists,

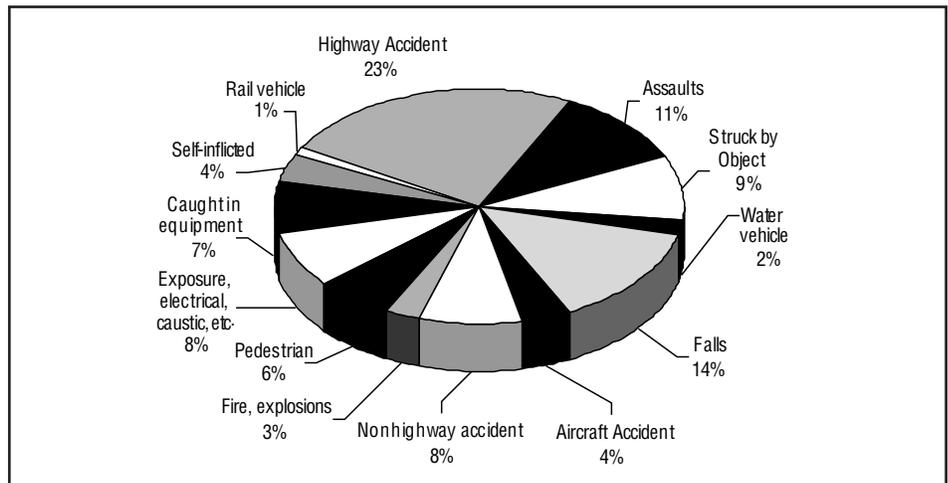


Figure 3–10: Fatal Occupational Injuries by Event, 2001

Adapted from: Bureau of Labor Statistics, <http://www.bls.gov/news.release/cfoi.t03.htm>

26 physicians, 18 registered nurses, 17 nurses' aides, and 18 health care workers in other occupational categories. A separate study using the National Traumatic Occupational Fatality database reported that there were 69 nurses killed at work between 1983 and 1989.

In a 1998 California study, they found that assault, hostage taking, rapes, robbery, and violent actions resulting in death were reported in emergency rooms, mental health hospitals and clinics, and social service offices. A 1983 study by Conn and Lion found that assaults by patients in the hospital setting occurred in psychiatric units (41%), emergency rooms (18%), medical units (13%), surgical units (8%), and even pediatric units (7%). A 1988 study by Lavoie et al., investigated 127 large, university-based hospital emergency departments and reported that 43% had at least one physical attack on a medical staff member per month. Seven percent of the reported acts of violence over a 5-year period resulted in death.

Violence in the emergency department (ED) has seen an increase in recent years. ED personnel face a significant risk of injury from assaults by patients and are often abused by relatives of patients or other persons associated with the patient. A study in the *Journal of Emergency Nursing* by Erickson and Williams-Evans found that 82% of nurses surveyed reported they had been assaulted during their careers—many going unreported. Stultz, in 1993 reported that nurses were the most frequent targets of assault and the

greatest percentage (25%) of assaults occurred in the ED. Of 51 homicides involving health care workers, 23% were in the ED.

Unfortunately, air medical personnel are not immune to violent assaults. In January 2002, two flight crewmembers heard a motor vehicle collision on the street adjacent to their base. Upon approaching the vehicle to assist the driver, the two flight team members were shot—one fatally.

Health care workers are exposed to other dangers as well, with the risk of needlestick injury and the transmission of bloodborne pathogens is an industry-wide concern. These injuries can result in serious and potentially fatal infections from the hepatitis B virus (HBV), hepatitis C virus (HCV), or human immunodeficiency virus (HIV).

In the United States, there are more than 8 million health care workers in hospitals and other health care settings. Estimates suggest that 600,000 to 800,000 needlestick injuries occur annually, with about half going unreported. A 1999 study by the National Institute for Occupational Safety and Health estimates that in the average hospital, workers will incur approximately 30 needlestick injuries per 100 beds per year.

In the United States, between 1985 and 1999, there were 55 “documented” cases and 136 “possible” cases of occupational HIV transmission to health care workers. Combined data from more than 20 worldwide studies of health care workers exposed to HIV-infected blood found

an average transmission rate of 0.3% (21 infections in 6,498 exposures).

HBV infections occur much more commonly in health care workers. In 1995 alone, an estimated 800 health care workers became infected with this virus. The HBV transmission rate after a single needlestick exposure ranges from 6 to 30% if the health care worker is not immune to HBV. However, treated with hepatitis B immune globulin and initiating the hepatitis B vaccine is more than 90% effective in preventing HBV infection. About one-third to one-half of persons with acute HBV infection develop symptoms of hepatitis. Most acute infections resolve, but 5% to 10% of patients develop chronic HBV infection that carries an estimated 20% risk of dying from cirrhosis and 6% risk of dying from liver cancer.

Hepatitis C virus infection, the most common chronic bloodborne infection in the U.S., is prevalent in 1 to 2% of the general population. Of the acute HCV infections that have occurred annually, 2% to 4% have been in health care workers exposed to blood in the workplace. Unlike HBV, chronic infection develops in 75 to 85% of patients, with active liver disease developing in 70%. Of the patients with active liver disease, 10% to 20% develop cirrhosis, and 1% to 5% develop liver cancer. On the average, 1.8% of the health care workers with percutaneous exposure to HCV become infected.

Another potentially dangerous and risky endeavor for many occupations, especially health care workers, is rotating shift work. Investigators have shown that disruptions in circadian phases due to rotating shift work are associated with decreased performance, lapses of attention, and increased reaction time. In 1992, Gold et al., found that nurses on rotating schedules reported more "accidents" (including on-the-job errors, on-the-job personal injuries, and auto accidents due to sleepiness) than did nurses on other schedules.

Sleepiness has been blamed for approximately 200,000 to 400,000 motor-vehicle collisions per year in the United States. Considering that the National Highway Traffic Safety Administration (NHTSA) recorded 6,279,043 motor-vehicle accidents in 1999, sleepiness would account for 3.2 to 6.4% of the accidents that year. In comparison,

NHTSA estimates that alcohol was involved in 7% of all crashes in 1999.

The practice of driving home after a night shift appears to be a significant occupational risk for health care workers. Steele (1996) reported the results of a survey of emergency medicine residents that found nearly 75% of the auto accidents and 80% of the near-crashes occurred following a night shift. That same year, Novak reported that approximately 95% of night nurses working 12-hour shifts reported having had an automobile accident or near-miss accident while driving home from night work.

Travel-Related Risks

How we choose to travel to work, during work, or for recreation predisposes each of us to additional risks. Travel-related deaths account for nearly half of all accidental deaths, with passenger cars and taxis having a significantly higher death rate than all other modes of travel (Figure 3-11).

There is a motor-vehicle death every 13 minutes. However, mile for mile, it is far riskier to walk or jog—if it involves crossing an intersection—than to use any form of motorized vehicle, including motorcycles. Pedestrian deaths, estimated at nearly 6,000 each year, are more than double the rate of motorcycle deaths.

Figure 3-11 depicts the death rates per 100,000,000 miles of travel for a three-year period for the major modes of transportation. From 1997-1999, scheduled airlines were the safest mode of transportation. Transit buses and school buses were next, but had ten times the death rate when compared to the airlines. Fatalities by automobile were about 22 times greater per passenger-mile than by city bus. In 22 years, HEMS has flown an estimated 3,002,176 hours, covering an estimated 360,261,121 miles (using an average of 120 miles-per-hour). Normalizing our HEMS data for 137 crewmember fatalities yields a death rate of 38.0 per 100,000,000 miles traveled.

How do you manage the risk of being involved in an auto accident? While automobile accidents kill a great many people, there are ways to manage the risk and reduce your chances of suffering a fatal auto injury. In motor-vehicle collisions,

Mode of Transportation	Death Rate
Buses	0.04
Railroad	0.06
Scheduled Airlines	0.004
Passenger Cars and Taxis	0.87
HEMS	38.0

Figure 3-11: Transportation Accident Death Rates / 100,000,000 miles, 1997 to 1999

Adapted in part from: National Safety Council, *Injury Facts 2001 Edition*

sions, large cars are generally safer than small ones. You are roughly twice as likely to die in a serious auto accident if you are in a small car rather than a large car. Yet, for various reasons, many of us choose to drive small cars. Driving at night, mile for mile, is almost four times more likely to end in a fatal accident than driving during the daylight. Yet most people still drive at night. The lap-shoulder seat belt reduces fatalities in front-end collisions by 42%, but it is reported that 32% of Americans never wear seat belts. However, when you take into account car size and seat belt use, you are less likely to die in a large vehicle accident wearing no seat belt than in a small car wearing a seat belt.

Helmets are an important consideration when it comes to bicycles and motorcycles. Helmets reduce the risk of fatal injury to motorcyclists by 30%. Helmets can also reduce the risk of serious head injury in bicycle accidents by more than 70%.

Ground Ambulance Accidents

Emergency vehicle accidents are not unique to air medical transport. A frequent discussion among transport professionals and other health care providers involves comparing the risk vs. benefit of ground vs. air transport. EMTALA guidelines require that the risks and benefits of all inter-facility transfers be explained to the patient. This should include an explanation of the anticipated risks and benefits of the chosen mode of travel—air or ground.

Unfortunately, the availability and accuracy of statistics regarding ground ambulance accidents is even worse than that of air medical transport. Similar to HEMS, no exposure data exists for

ground ambulances. There is no information nationwide as to the number of miles traveled, number of ambulances or the number of patients transported. The lack of this information makes it impossible to make a meaningful comparison between air and ground transport. However, some information is available regarding ambulance accidents.

The National Safety Council publishes data on crashes involving emergency vehicles in the United States. The NSC annual tabulations are based upon the Fatality Analysis Reporting System (FARS) and General Estimates System (GES) which are made available each year from the National Highway and Safety Administration. However, experts in the field of ground EMS transport question the accuracy of these statistics. There is no central tracking system to identify and capture ground ambulance accidents. Some accidents will be reported as “ground ambulance” accidents. In some systems, however, where EMS is a component of the Fire Department, the accident may be logged as having involved a “fire” vehicle. Some accident reports may list the vehicle as a “light truck.” Some states track ground ambulances aggressively. In New York State alone, there are an average of 350 ambulance accidents each year, injuring an average of 2 people per day. However, many states do not have any system in place to track accidents accurately.

In April 2002, Robert Davis reported in *USA Today* that there might be an estimated 15,000 ambulance crashes a year. This estimate is approximately three times the number of ground ambulance accidents that we find in the NSC annual publications. Other sources suggest from sample data that it is very reason-

able to estimate one fatal ambulance crash each week, as many as ten serious injuries every day and as many as 10,000 total injuries every year. Figure 3–12 presents three years of NSC data for ground ambulances, as well as other emergency vehicles (police and fire).

USA Today reported that with “relatively few fatalities each year (. . . out of millions of ambulance calls), federal officials say there is no pattern that triggers any alarms,” and “. . . there is not a huge safety problem.”

There are obviously those who would disagree.

USA Today referenced a 1993 Houston study that found that ambulances were 13 times more likely to be involved in an accident than other vehicles based upon the number of accidents per miles driven. That study also determined that ambulances were five times more likely to be involved in an accident that resulted in injuries.

Our analysis of the NSC data for 1997–1999, found that ground ambulance had the highest percentage of fatal accidents when comparing each category of emergency vehicle. Over the 3-year period, 0.47% of all ground ambulance accidents resulted in a fatal injury. Fire vehicles were a little better at 0.39% and police were 0.32%. In addition, if you consider the number of total fatal injuries per 1,000 emergency vehicle accidents, the ambulance remains the most lethal. Over the 3-year period, the ambulance averaged 5.2 fatal injuries per 1,000 accidents, compared to 4.8 deaths for fire vehicles and 3.49 for police. The percentage of accidents that resulted in injuries is also the highest for ambulances (36%) compared to the fire (18%) and police (32%) vehicles.

From the 1997–1999 NSC data, in fatal, multi-vehicle ambulance accidents, only 25% of the deaths were occupants of the ambulance. Less than 3% of the fatalities were the ambulance “driver” according to the NSC data. Over 22% of those killed were “emergency vehicle passengers”. The NSC tables did not differentiate between the patients, medical personnel, patient’s family or others who were killed in the ambulance, making it impossible to know the total number of ground ambulance personnel killed in accidents. Of the remaining fatalities, two-thirds of those killed in these accidents were occupants of another vehicle and 8% of the fatalities were nonmotorists.

Recreational Risks

When it comes to sports and recreational activities, the National Safety Council and other publications make little if any effort to compare or rank the relative risk of injury or death. There are too many variables and unknowns to consider, including frequency and duration of exposure, number of participants and accurate numbers of injuries. The only injuries generally known are those that required emergency treatment. Most of the statistics come from emergency department logs.

The rising popularity of extreme sports was documented in the 1999 *Time* magazine article.

More Americans than ever are injuring themselves while pushing their personal recreational limits. BASE jumping (jumping from Buildings, Antennas, Span/bridges and Earth/cliffs) has one of the sporting world’s highest fatality rates. In its 18-year history, 46 participants

have been killed.

Currently, there are more than a thousand jumpers in the U.S. and more getting into it every day. The sport has never been more popular.

While there has been a steady decline throughout the ’90s in the participation in sports like baseball, touch football, and aerobics, there has been rapid growth in adventure

	Ambulance				Fire Truck/Car				Police Car			
	97	98	99	Avg.	97	98	99	Avg.	97	98	99	Avg.
EV in fatal MVA	28	25	15	0.47%	20	17	17	0.39%	97	83	65	0.32%
EV in injury MVA	1,465	2,306	1,473	36.4%	997	781	677	17.6%	8,305	8,210	8,645	32.4%
Total number of MVAs	4,745	4,615	5,050		3,928	3,188	6,839		23,725	24,417	29,419	
EV driver killed	0	2	0	2.7%	5	4	5	21.2%	19	17	17	19.6%
EV passengers killed	8	7	2	22.7%	3	3	3	34.8%	6	3	4	24.4%
OV occupants killed	21	18	11	66.7%	13	12	9	51.5%	54	66	40	59.0%
Nonmotorist killed	2	2	2	8.0%	4	3	2	13.6%	24	10	11	16.6%
Total Deaths	31	29	15		25	22	19		103	96	72	
Total injuries	3,351	3,274	2,659		1,467	1,035	1,130		12,689	12,339	15,230	

Figure 3–12: Emergency Vehicles Involved in Motor Vehicle Accidents, 1997–1999 (EV=Emergency vehicle; OV=Other Vehicle)

Adapted from: *Injury Facts: 1999 Edition, 2000 Edition, and 2001 Edition*. National Safety Council.

sports. Snowboarding has grown 113% in five years and now boasts nearly 5.5 million participants. Mountain biking, skateboarding, scuba diving, and other more hazardous activities have seen more and more people participate. In 1997 the U.S. Consumer Products Safety Commission reported that 48,000 people were treated in hospital emergency rooms with skateboarding-related injuries—33% more than the previous year. Visits to the E.R. were also up for snowboarding injuries (up 31%) and mountain climbing (up 20%). The US Parachute Association reports that 10% of skydivers suffer injuries requiring medical attention. Annually, there are approximately 30 deaths, or 1.2 deaths per 100,000 jumps. In contrast, there have been only 20 serious injuries reported from an estimated 1,000,000 bungee jumps between 1988 to 1994. During the same time there were 7 deaths, for a death rate of 0.7 per 100,000 jumps.

Recreational Activity	Injury Rate
Skydiving	10%
Hockey	4.08%
Rugby	2.4%
Basketball	1.94%
Football	1.66%
Snowmobiling	1.34%
Bicycle Riding	1.21%
Baseball/Softball	1.07%
Skateboarding	0.76%
Roller/In-line Skating	0.41%

Figure 3-13 Adapted: National Safety Council, *Injury Facts 1999 Edition*

Some participation and injury statistics were available from the National Safety Council and other sources. While the accuracy of injury rates may not be precise for the reasons previously mentioned, some calculations are presented for comparison.

Any meaningful comparison between recreational injury rates and work-related injuries may be difficult. However, if you look at the “all industry” occupational injury rate of 2.86%, it would suggest that you are more likely to get injured on the job than participating in any of the above sports except hockey. On the other hand, looking at the injury rate for HEMS personnel of 0.16%, it would seem that you are less likely to get injured in a helicopter accident than participating in these sports.

SECTION 4: SAFETY AND RISK MANAGEMENT IN HEMS

No report on HEMS safety would be complete without trying to identify ways to enhance program (and industry) safety and reduce risk. While every air medical program has similar exposure characteristics, no two programs are exactly alike. This section will look at four basic requirements of a safety program, introduce some key aspects of risk management, and then highlight the benefits of a multidisciplinary approach to improve safety.

PRINCIPLES OF A SAFETY AND RISK MANAGEMENT PROGRAM

A safety and risk management program for an air medical program must encompass two aspects. Most important is doing everything possible to prevent an accident from occurring. If this fails and an accident does happen, everything must be in place to mitigate the impact of the accident.

Being safe does not eliminate risk—it reduces it. There are four basic principles that should guide the coordination, implementation, and evolution of a safety and risk management program for air medical operations. These principles are attitude, participation, education, and judgment.

Attitude

Safety does not just happen, it is not a specific event or a “thing”—it is an attitude. This perhaps is the most important component of the safety equation and may override all other aspects and variables. Everyone must have the right attitude about safety in order to participate and survive in an air medical transport program. This, along with a commitment to safety, is essential and must be exhibited by every crewmember and every manager. The attitudes should reflect the mission that safety *must* be the program’s number one priority.

A number of obstacles may prevent the development of a sound safety program. An FAA Advisory Circular (AC) No. 60-22 defines attitude as “a personal

motivational predisposition to respond to persons, situations, or events in a given manner that can, nevertheless, be changed or modified through training.” Negative attitudes, however, are particularly difficult to overcome. Some people may think that safety is not their responsibility and their actions are not likely to impact the safety of flight or result in an accident. In some cases, identifying potential problems may seem to be too threatening to discuss and may simply be avoided. In other circumstances, denial occurs as team members insist that there is no safety problem.

Complacency is another serious problem and in many ways may represent a negative attitude. Merriam-Webster’s Collegiate Dictionary defines complacency as “self-satisfaction accompanied by unawareness of actual dangers or deficiencies.” Having learned things before or having done certain activities in the past may result in overconfidence and eventually to errors in performance. Never having an accident or incident does not assure continued safety if it results in complacent attitudes. It results in smart people sometimes doing dumb things. In 1901, Wilbur Wright wrote, “Carelessness and overconfidence are usually more dangerous than deliberately accepted risks.” One hundred years later, this statement is still appropriate.

In 1997, the pilot of an Aerospatiale AS-365N Dauphin transported two passengers to a corporate ramp at Indianapolis International Airport. Upon shutting down the engines and applying the rotor brake, one passenger exited and walked forward of the helicopter and turned into the path of the rotor system. The passenger was struck in the left temple by a main-rotor blade and killed. In January 2001, a hospital security guard walked into the tail rotor of a Bell 206L as the helicopter was preparing to depart the base hospital helipad. The security guard died of his injuries. It may be very difficult to determine if complacency, carelessness, or overconfidence were contributing factors in these accidents.

Participation

A safety program must be planned, instituted and practiced every day and

on every flight. It is not enough to assume that hospital administration, program management, the pilots, or the aviation operator will be completely responsible for safety. The safety program must be multidisciplinary and responsive in order to be successful. Safety is dynamic. Things change. Crewmembers (pilots, mechanics, medical and communications) come and go, aircraft may change (primary or backup), weather conditions vary, and a program may fly to hundreds of different locations. Every flight is different. It takes teamwork, where individuals interact effectively and efficiently with fellow crewmembers to maintain a safe aviation operation.

There is no such thing as a “free ride.” Whatever the role of a team member in the program, each individual must acknowledge the critical fact that safety is their prime responsibility. It requires active participation, rather than passive observation. While medical personnel are not expected to be experts in aviation, each must be proficient with their safety-related responsibilities. At times, when delivery of medical care and safety may seem to come into conflict, safety *must* always take priority.

Each crewmember must recognize his/her role to help identify, address, and help resolve (as appropriate) potential safety concerns. Every situation represents an opportunity to learn and to improve. A program should encourage every member to identify opportunities for improvement, either to enhance program safety or efficiency.

Education

Education is a key ingredient in identifying, understanding, and actively managing risk. For a pilot and air medical crew, being knowledgeable of the elements that may increase or decrease the related risk should lead to taking appropriate steps to minimize unnecessary exposure. The result would be to greatly reduce the chance of being involved in an accident or incident.

There are many aspects of education that may be considered part of a safety program geared to actively manage risk. Education and training obviously begin with the pilots and mechanics and continue with the medical crew and commu-

nication specialists. It must also include the security and public safety personnel who set up and/or secure landing zones or helipads.

Another important aspect of education is learning from past mistakes. In separate documents, both the Aircraft Owners and Pilots Association (AOPA) Air Safety Foundation and the Flight Safety Foundation support the belief that pilots can learn valuable lessons from analyses of past accidents and incidents. Accident data often yield clues to safer operations, and can be applied at relatively little cost and with no additional regulations. By analyzing mishaps, pilots, medical teams, and program administrators can learn about potential risks and take proactive steps to control them. The U.S. Air Force *Guide to Mishap Investigation* states, “the proper use of mishap experience is reducing mishap potential.”

It is important to realize that education isn’t everything—it is merely the beginning. Being able to apply the knowledge under routine and emergency conditions is expected of each and every crewmember. Each crewmember must be able to perform his or her safety-related functions proficiently and independently. It is an unnecessary distraction and risk for pilots and medical crewmembers to worry about someone else who does not do his/her job.

Judgment

FAA AC No. 60–22 defines judgment as “the mental process of recognizing and analyzing all pertinent information in a particular situation, a rational evaluation of alternative actions in response to it, and a timely decision on which action to take.” In 1986, Arthur Negrette authored an article entitled “Spatial Orientation: It Plays No Favorites.” He reported that on the average, it takes a helicopter pilot five seconds to recognize a hazard, determine the necessary corrective action, and respond.

Some people feel that good judgment is an inherent characteristic and not one that can be easily taught. Someone may be given the tools through education and months or even years of experience, but may still lack the ability to put it all together for optimal performance and outcome.

The AC goes on to define the Poor Judgment (PJ) Chain as “a series of mistakes that may lead to an accident or incident.” The AC states that there are two basic principles that are generally associated with the creation of a PJ chain: (1) one bad decision often leads to another; and (2) as a string of bad decisions grow, it reduces the number of subsequent alternatives for continued safe flight.

In the HEMS environment with its limited resources (generally one pilot and two medical crewmembers), it is essential for each and every crewmember to be at the top of their game, using sound judgment to recognize individual limitations and changing conditions. Having alternate plans and knowing when to implement them can impact both aviation and medical safety. For example, in aviation, judgment is key when it comes to the decision to initiate a flight or when to abort a flight. In medicine, it may be exemplified in your management of the patient with a difficult airway. What drugs, if any, should be considered? What is the backup plan if the intubation is not successful? Having the knowledge and the skill is essential. Sound judgment and proficiency are more likely to yield a positive outcome. In HEMS this will enhance overall safety.

RISK MANAGEMENT

Risk management is a discipline for dealing with uncertainty; a science of looking to the future through today’s vision. It enables us to make a range of informed decisions about our environment, health, safety, and our social and economic well being. It is about managing resources wisely, protecting from harm, and safeguarding assets. In HEMS, risk management should be directed toward optimal flight safety as well as providing the highest quality of medical care.

Effective risk management acknowledges and identifies threats, evaluates and prioritizes the risks, considers the probability a risk will materialize, and controls loss (preventing loss and reducing the severity should a loss occur). Results must be evaluated and strategies revised as appropriate. With this information, a person or organization is able to make an informed decision as to how they will deal with various risks.

Identifying Risks

In this report, we have already identified many of the issues that could represent threats to the safety of flight. In the reports from the Air Medical Accident Analysis and the Helicopter Accident Analysis Team specific problems that have led to accidents are identified.

Additional information is obtained from the *AirMed* “2000 Aircrew Survey” that identified the situations that HEMS pilots felt posed the greatest threats (i.e., greatest risk) to flight safety. Scene operations (64%), program complacency (44%), and mission-related stress (35%) were the three most common concerns. Figure 4–1 shows the various risks that were identified.

A more comprehensive “EMS Line Pilot Survey” was conducted by NEMSPA and HAI in 2000–2001, which yielded a combined total of 304 responses. In general, there were considerably more variables to choose from in this survey, which often resulted in lower percentages for each specific response.

The greatest risk to safety industry-wide was found to be management or crew pressure (11%). Inexperience was next (9%), followed by LZ operations/hazards and weather reporting/forecasting at 8% each. At 7% were poor decision-making, night operations, and marginal VFR/inadvertent IFR conditions. When asked what risk factors contributed to accidents in recent years, the most common response was pushing weather minimums (14%), followed by complacency (11%), pilot complacency (10%), inexperience (8%), and lack of IFR training (8%).

There were a number of questions in the “EMS Line Pilot Survey” that further clarified the types of pressure the pilots identified, as seen in Figure 4–2.

Dealing with Risks

Techniques to Control Risk

There are six techniques to control risk. The first and most common option is *risk avoidance*. If it is not worth assuming the risk, avoiding the exposure may eliminate the risk. In air medical transport, an alternative would be ground transport, which has its own inherent risks. A program could also decide that

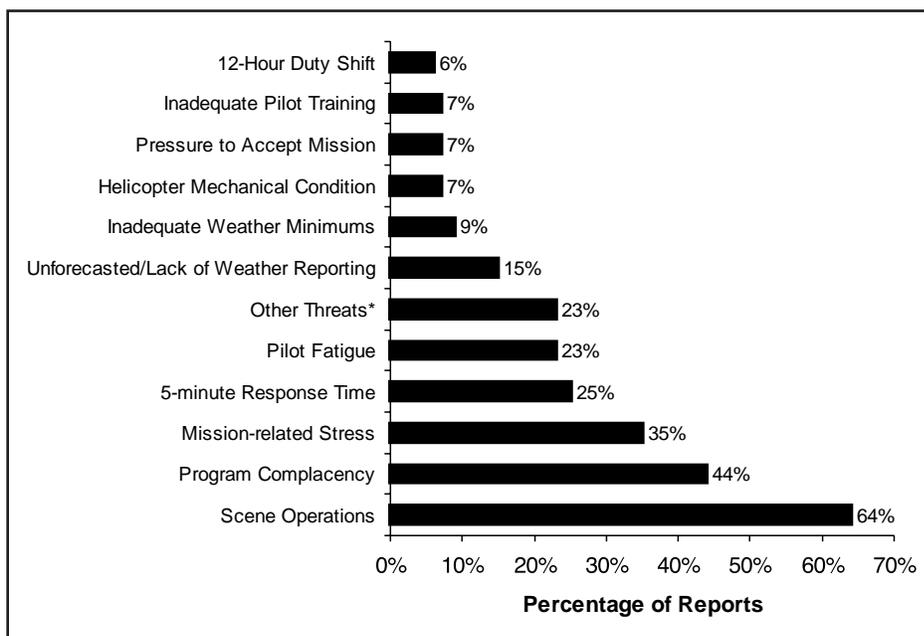


Figure 4–1: Greatest Threats to Flight Safety (n=148)

*“Other threats” included night operation, general aviation traffic and negotiating geography/mountainous terrain and others. Adapted from: Rau, 2000 Aircrew Survey, *AirMed*, Nov/Dec, 2000

Survey Variable	Response
Undue pressure from:	
Program Management	32%
Flight crews	14%
Operator	13%
Dispatch	13%
Pressure from:	
Crew/management to speed up response or lift-off times	55%
Other pilots (indirectly) to launch/continue in marginal weather	13%
Crew/management to launch/continue in marginal weather	8%
Pilots pressure themselves to:	
Launch/continue in marginal conditions	13%
Fly when fatigued or ill	32%
Speed up response or lift-off times	48%

Figure 4–2: Pilot-related Pressures (n = 304)

Adapted from: EMS Line Pilot Survey, NEMSPA and HAI, 2001

scene accidents or flying at night pose too great a threat and elect to avoid these situations.

The second option is *risk prevention*. In this situation, the HEMS program would take the necessary action to try to prevent a loss through comprehensive training (pilots, medical crews and communicators), policies and procedures, and so on. A helicopter program may choose to do scene flights only during the day or only land at pre-designated landing zones. A program may also conclude that a twin-engine aircraft is less

likely to have a potentially catastrophic malfunction (i.e., engine failure of a single-engine helicopter) or that two pilots will reduce the likelihood of pilot error. All of these options strive to decrease the possibility of an aircraft accident, but do not eliminate all possibility of that loss.

The third technique is *loss reduction*, which is an attempt to reduce the severity of the loss. The decision to wear helmets or nomex are forms of loss reduction in HEMS. Survival training and appropriate survival gear may also reduce the losses in an accident, but do nothing

to prevent an accident from occurring.

Segregation of risk is the next alternative. While the technique has similar characteristics to loss reduction, it also has very distinct features. A program may choose to have separate helipads for their multi-helicopter program or for a visiting aircraft to use. If a helipad accident were to occur, only one helicopter would be involved. Some families use this technique to control the risk of travel on commercial airlines. Rather than all flying together on one airplane, the family will split up, taking two different flights, reducing the risk of an accident taking an entire family.

The next alternative is *risk transfer*, when someone else assumes the risk. In HEMS, this could include not having a flight program or having another flight program undertake your transports (similar to risk avoidance). It may also be a factor in considering who is responsible for the various aspects of the Part 135 aviation operation; who is responsible for the training of the pilots and mechanics; or who is responsible for the maintenance of the aircraft and compliance with all Federal Aviation Regulations. It could be the hospital or flight program, or this could be transferred to a full-time aviation operator. Risk transfer can also be represented by the various hull, liability, disability, and life insurance policies that are in place to address various losses. Power-by-hour is yet another form of risk transfer.

Risk retention is the final option, where a program or individual consciously assumes the risk, taking no specific steps to reduce the risk or the severity of a loss.

HEMS-Specific Risks

Dozens of intervention strategies have been recommended in the Air Medical Accident Analysis and the HAAT report. It is appropriate to highlight specific HEMS risks and several considerations to deal with these risks.

Scene Operations. The concern over scene operations, as identified in Figure 4-1, is long standing and justified—especially at night. Potential landing zone (LZ) hazards (trees, wires, etc.) represent a significant threat to safety. To improve safety, 9% of the responses to the “EMS Line Pilot Survey” favored night vision goggles.

Education plays an important role in scene safety. Educating pre-hospital personnel on the selection and preparation of the LZ is key. Educating the medical crew and their active participation to look for hazards on approach and landing is also essential. However, as the statistics showed, very few of the accidents that occurred on “scene” flights occurred while landing at the scene. More accidents occurred with the patient on board than on any other leg of the scene missions.

Complacency. Program complacency has already been addressed. It is important for pilots, crewmembers, communication specialists and administrators to recognize that complacency may be the greatest danger in HEMS—the silent killer. The complacent individual generally exhibits a low level of awareness and does not recognize the need for action or involvement. This leads to mistakes.

Someone once was asked, “What is the difference between ignorance and complacency?” he responded, “I don’t know and I don’t care.”

Pressure and Stress. Mission-related stress has also been addressed, in part, with regard to both self-imposed and externally imposed pressure. In 1988, the NTSB report recognized both of these pressures as significant concerns. Thirteen years later, the “EMS Line Pilot Survey” identified management or crew pressure as the greatest risk to safety industry-wide. Have we made no progress over the past decade?

Weather. It is of interest that two factors that scored fairly low in Figure 4-1 were pilot training (7%) and unforecasted/lack of weather reporting (15%). In the *AirMed* pilots’ survey, 85% of the pilots reported having made a forced landing once or twice in their HEMS career for deteriorating weather conditions. A responding 32% reported at least one forced or precautionary landing during the past year due to weather. This would seem to imply that the pilot’s ability to identify and actively manage a risk diminishes the perception of a particular threat to safety. On the other hand, concerns that they may have little direct control over (i.e., scene LZs, program complacency, etc.) remain significant

threats.

Weather, however, remains an all too common factor in HEMS accidents. Despite thorough planning and adherence to weather minimums, it is possible for any HEMS pilot to encounter unanticipated weather and enter inadvertent instrument meteorological conditions (IMC). The first line of defense for any pilot against inadvertent IMC is to take the necessary steps to avoid the situation. Comprehensive weather planning is perhaps the most important step. This should include access to updated weather forecasts and a working knowledge of weather charts and reports, as well as familiarity with local weather trends. Forecasts are not guarantees but forecasts for marginal conditions are usually accurate. It is only a short step from marginal conditions to unflyable conditions. A marginal forecast and wishful thinking that “the weather won’t be as bad as they say” has no place in aviation, especially air medical transport.

The pilot’s actions immediately after encountering IMC will determine the outcome of the flight. In many weather accidents the pilot waited just a little too long to change his mind. In a significant number, deciding to divert only a few minutes earlier would have kept the flight out of danger. Trained and proficient pilots, who have a plan of action in the event of inadvertent IMC, are more likely to experience a successful outcome. Another important defense against inadvertent IMC is a willingness to land the aircraft. Such willingness runs counter to the pressures HEMS pilots sometimes feel to complete their missions.

Although it is impossible to make a direct correlation, more experience in weather-related decision making should result in a gradual reduction in some of the VFR into IMC accidents and incidents.

Night and Spatial Disorientation. Flying at night poses its own unique risks in aviation. This is especially true in HEMS. The FAA manual, *Aeronautical Decision Making for Air Ambulance Helicopter Pilots*, notes that “even on the clearest night with VFR (visual flight rules) conditions, a pilot can come close to IFR (instrument flight rules, i.e., inadvertent IMC) operations if there is no moon and/or no ground lights to estab-

lish a horizon reference.” In contrast, there could be an abundance of ground lights below and stars above that can seem to merge into a continuous sweep of pinpoints that can deprive a pilot of any horizon reference. In both situations, with the loss of the visual reference (the ground and/or horizon), the interpretation of motion and position in relation to the environment may be lost. An inexperienced pilot who becomes disoriented, or who does not trust his/her instruments, may change direction, altitude, speed, etc., and if unable to compensate is likely to have an accident.

Another risk lurking in the night sky is the unseen cloud. Clouds disappear easily in the dark and a pilot can fly into one without seeing it coming. In all of these nighttime situations, instrument training and proficiency may help mitigate the potential risk.

FAA Advisory Circular 60-4A (February, 1983) addresses pilot's spatial disorientation. In this AC, it states: “Tests conducted with qualified instrument pilots indicate that it can take as much as 35 seconds to establish full control by instruments after the loss of visual reference with the surface.” While the tests were performed on fixed-wing aircraft, the results may be more dramatic with helicopters since they require even more pilot intervention to maintain control.

Another group of fixed-wing pilots were asked to identify their personal experience with spatial disorientation. The most common sensory illusions reported were:

- A sensation that one wing was low although wings were level (60%)
- On leveling after banking, a tendency to bank in opposite direction (45%)
- When in a turn, a feeling as if they were straight and level (39%)
- Becoming confused in attempting to mix “contact” and instrument cues (34%)
- On recovery from a steep climbing turn, the feeling of turning in the opposite direction (29%)

This AC also points out that while visibility may be above VFR minimum, the natural horizon and surface references may at times become obscured in low-

visibility conditions, on over-water flights, and at night—especially in sparsely populated areas. The AC concludes “You and only you have full knowledge of your limitations. Know these limitations and be guided by them.”

Pilot Training and Experience. This leads directly into the issue of pilot training and experience. In the *AirMed* survey, pilot training scored very low as a perceived risk to flight safety.

In the HAI/NEMSPA survey, however, when asked “what can be done to improve industry safety,” the most common response was to improve the quality and frequency of training (17%).

The Frazer articles and Hart lectures have concluded that in the vast majority of HEMS accidents, this did not appear to be a major factor. This report is not about to address specific training requirements for the aviation (pilots and mechanics) professionals. However, a study by FlightSafety International (FSI) seems worthy of mention.

FlightSafety offers flight simulator training for both fixed-wing and rotor-wing pilots. Their full-motion simulators can reproduce various in-flight emergencies during various lighting and weather conditions. FSI conducted a study to determine the impact that simulator training had on the fixed-wing fatal accident rate. FSI estimates that they trained approximately 20% of the fixed-wing pilot population. Looking at five years of accident data, they identified a total of 471 accidents, or an average of 94 per year. They postulated that if simulator training made *no* difference, the FlightSafety trained pilots should have accounted for approximately 20% (92) of the total accidents. Instead, the FSI-trained pilots had only 3% (15) of the total accidents. The expected accident frequency was reduced by more than 80%. FlightSafety concluded that: “The benefits of simulator training are obvious...and the safety record proves it.”

While simulator training may indeed be beneficial, other considerations may also be factors. It is also possible that the companies that went to the effort and expense of sending their pilots to simulator training are more safety-proactive in other areas as well.

Of interest, the *Air Medical Accident*

Analysis rated full-motion simulators as highly effective, but low feasibility. Perhaps more interesting is the response to the “EMS Line Pilot Survey” when asked “what can be done to improve industry safety?” Of the 304 responses, only one selected “simulation.”

AIR MEDICAL RESOURCE MANAGEMENT

Air Medical Resource Management (AMRM) is not a unique concept. Based upon more than 20 years of business and aviation models, AMRM is specifically designed for our industry. The goal is to provide the methodology to make optimum use of the capabilities of the individuals and aircraft systems to achieve the safest and most efficient completion of a flight.

In 1979, NASA suggested that business managerial concepts could be applied in the cockpit to reduce the high number of “human-factors” accidents occurring with the airlines. Within 10 years, *Cockpit Resource Management*—later expanded conceptually to *Crew Resource Management* (CRM)—was included in training worldwide at most major airlines. The U.S. Air Force had begun full-scale CRM training of all crews of multiperson aircraft. Today, there is sufficient evidence that CRM training and practice have improved aviation safety.

CRM is the effective *management* of all resources available to ensure that all group members are operating from a common frame of reference and toward a common goal of aviation safety. CRM provides a framework for accomplishing a given mission. In air medical transport, training programs have been and are being developed that teach CRM skills and principles not only to pilots, but also to medical personnel, communication specialists, maintenance personnel and management. In fact, at the 2000 Air Medical Safety Summit, the number one priority identified by the industry leaders (aviation, medical and management) was CRM and related training. At an all-day seminar prior to the Air Medical Transport Conference in September 2001, a new *Air Medical Resource Management Train-the-Trainer* course was presented for the first time.

The FAA's Advisory Circular identifies components of CRM to include teamwork, communication skills, decision making, workload management, situational awareness, preparation and planning, cockpit distractions, and stress management.

Teamwork is key in AMRM and must be maximized to facilitate the transfer of information. In HEMS, teamwork must include everyone who could impact the safety of flight, including the pilots, medical personnel, communication specialists, maintenance personnel, air traffic controllers (ATC), and management. Much like a sports team, each person must know his/her role, be an active participant and be able to execute his/her assignment when called upon. In sports, the goal is winning. In aviation, "winning" is a safe and efficient aviation operation resulting in the safe return of the aircraft and crew at the conclusion of each and every flight.

Effective communication skills are essential in developing teamwork. Pilots can increase the probability of a safe flight by overcoming barriers in communication and learning to effectively seek and evaluate information. Communication problems are often cited as a causal factor in aircraft accidents and incidents. At a recent air medical conference, a leading safety expert in HEMS stated, "open and effective communication might have prevented perhaps as many as 80% of EMS accidents."

Aeronautical Decision Making (ADM) refers to a systematic mental process used by pilots to consistently determine the best course of action in response to a given set of circumstances. ADM includes risk assessment and stress management. It also illustrates how personal attitudes can influence decision making and how those attitudes can be modified to enhance safety in the cockpit. Good decision making skills are not necessarily inherent and must be learned. A pilot must seek and evaluate all relevant information, using all available resources, before making an important decision. These resources may include people (medical crewmembers, ATC, communication specialists, other pilots) aircraft instruments, documentation (flight manuals, checklists, etc.), and sensations (vibrations, sights, smells, position).

Studies by a number of researchers have shown that there is a strong correlation between errors in decision making and the severity of accidents. While many skill-related problems may result in minor injuries and damage, faulty decision making processes often result in accidents with serious injuries and fatalities.

Situational Awareness is the accurate perception and understanding of all the factors and conditions going on around you. In aviation, this deals with the four fundamental risk elements that affect safety before, during, and after the flight—the pilot, the aircraft, the environment, and the type of operation that comprise any given aviation situation. This requires a pilot's full attention. Here too, cockpit distractions must be kept to a minimum. The Aviation Safety Reporting System (ASRS) identified pilot distraction as one of the most frequent causes cited in the reported incidents.

Managing the workload is critical to the single-pilot operation. Tasks must be carefully prioritized and the pilot must avoid being distracted from his/her primary duty of flying the aircraft. The single pilot can often benefit by utilizing his/her resources and sharing tasks. This could include having the medical crew handle some of the communications with dispatch or EMS ground personnel, looking for hazards while landing or taking off, requesting assistance or information from ATC or from dispatch, and prudently using automation such as an autopilot.

In the single-pilot HEMS operation, preflight planning and preparation is of special importance. Generally, no one else is available to confirm radio frequencies and make radio calls, fix positions and call out checklists. In a high-workload or stressful situation, the pilot must be able to call upon his/her training and items that may have been committed to memory, such as frequencies and emergency procedures, that otherwise might be difficult to confirm in an emergency. In addition, as appropriate, the pilot should utilize the other resources that may be available.

The effects of stress are often difficult to recognize and the inability to recognize this may be hazardous in aviation. Failure to manage stress often leads to eroded judgment, errors in decision making, decreased work performance, inat-

attention, degraded communication skills, preoccupation, and complacency. A pilot suffering from stress may forget or skip procedural steps, accept lower performance standards, and exhibit a tendency toward spatial disorientation and misperceptions. These misperceptions may result in misreading maps, charts and checklists, misjudgment of distance and altitude, and loss of time perception. In a study of more than 700 naval aviators who had been involved in major aircraft mishaps over a four-year period, it was discovered that those pilots who exhibited the symptoms of inadequate stress coping were more likely to be involved in an aircraft mishap.

As you can see, the elements of AMRM are intertwined and do not stand alone. Together, they can be used to improve work performance and the safety margin in air medical transport. But crew resource management is not restricted to the aircraft. It can also be an essential learning tool for people who work together in any environment, including the emergency department or trauma room.

The Air Medical Accident Analysis recommended CRM training as highly effective and moderately feasible. The HAI/NEMSPA survey seemed to agree. Of the responses, 63% of the pilots surveyed found CRM effective in making the program safer and 41% found that CRM made the program more efficient. Unfortunately, the pilot survey also shows that we have several hurdles before us. A total of 38% of the respondents found CRM to be ineffective because it "doesn't work here" (3%), was not well presented (8%) or due to a lack of support from the program (6%), operator (3%), flight crew (9%) and some of the pilots (10%). The lack of support by some of the pilots is not surprising, as CRM proposes a way of doing things that is contrary to the way many pilots have trained and flown for years. Historically, pilot training leaves the pilot-in-command (PIC) as the sole arbitrator as to how to conduct a flight. With AMRM, the PIC is still fully responsible but is encouraged to involve others who may be in a position to contribute to the decision-making process on behalf of safety.

SECTION 5: CONCLUSION

Every occupation has inherent risks. Medical professionals and transportation professionals are no different and are exposed to various risks every day. Transport Medicine combines these two fields into a unique medical specialty where the aviation and medical professionals face uncommon challenges and risks every day.

The risk of a helicopter accident is very real in HEMS. Since 1972, it is estimated that HEMS has flown an estimated 3.0 million hours while transporting approximately 2.75 million patients. In 31 years (through September 2002) there have been 162 accidents involving dedicated medical helicopters and four accidents involving dual-purpose helicopters in the United States. In 67 fatal accidents, 183 people have lost their lives, including 144 crewmembers. In the early and mid-1980s, during the HEMS industry's most rapid growth, we experienced an alarming number of accidents. The early and mid-1990s showed improvement, but 1998 to 2001 again showed an increase in the number of HEMS accidents across the nation. Despite this recent increase, however, the percentage of fatal accidents has declined by more than a third compared to the early 1980s. The fact remains, however, that since 1990, there has been an average of 2.5 fatal accidents annually, taking the lives of 5 to 6 crewmembers each year.

It must be pointed out that for all of the data that has been reviewed and analyzed in this report, many of our numbers are very small. To draw conclusions over a five-year or 20-year period may be somewhat reasonable. However, many of our calculations are greatly distorted due to the small numbers for year-to-year comparisons. Due to a low occurrence rate, aircraft accidents are poor indicators of safety trends. In addition, there may be limited first-hand information available as to the real cause of an accident if the accident resulted in fatalities.

There is no typical HEMS accident. However, several observations are noted. A disproportionate number of HEMS accidents occurred during night operations, during the cruise phase of flight,

and on scene transports. Pilot error was attributed as the direct or indirect cause of HEMS accidents approximately three times more often than mechanical failure. Of the pilot errors, one-third were weather related.

In 1988, the NTSB concluded that poor weather poses the greatest single hazard to EMS helicopter operations. More than a decade later, deteriorating weather conditions continue to represent a significant risk in HEMS. In general, the cause of the weather-related accidents does not appear to be a pilot's disregard for established weather minimums at takeoff. Instead, it is the pilot's encounter with instrument meteorological conditions en route. In general, weather may not cause the accident, but it may increase the likelihood that an accident will happen.

Weather is the second most common factor or cause of HEMS accidents. Of the weather-related HEMS accidents, over 85% occurred at night. Approximately 75% of all weather-related HEMS accidents resulted in fatalities. The correlation between weather-related accidents and cruise flight is very strong. Degrading weather conditions can significantly compromise a pilot's ability to see and avoid obstacles—especially while at cruise speed.

Pilot fatigue and total hours of flight time do not appear to be significant factors in HEMS accidents. Looking at HEMS incidents, however, suggests that IFR rating and currency may be very helpful, if not invaluable, to overcome a situation and avoid an accident. In addition, communication problems, time pressures, and distractions are frequently identified as contributing risk factors in HEMS incidents.

The magnitude of injuries and aircraft damage are significant considerations in HEMS accidents. HEMS accidents are more likely to result in fatalities or serious injuries than other helicopter accidents. While pre- and post-impact fires occur in only a small percentage of HEMS accidents, nearly half of all the accidents result in the destruction of the helicopter. No conclusions, however, can be made regarding single- vs. twin-engine aircraft.

Our HEMS accident rates and fatality rates are based upon estimated exposure

data. Data for the past fourteen years has been determined through several industry-wide surveys and various calculations. It is possible that our survey results have underestimated the number of HEMS programs and dedicated helicopters by ten percent or more. Therefore, our proposed exposure data may also be underestimated. As a result, our calculated accident and fatality rates could be overstated by an estimated ten percent. This difference, however, does not impact the overall trends identified in HEMS accidents nor our comparison with other aviation operations.

In the early and mid-1980s, the accident rate for HEMS was dramatically higher than all other aviation operations. Since 1987, however, we have seen a significant decrease in the HEMS accident rate to approximately one-third of what we experienced in the early to mid-1980s. The HEMS accident rate has remained consistently below the accident rates for both general aviation and all helicopter operations since the late 1980s. The fatality rate has also seen significant improvement since the late '80s. Despite a recent increase, the fatal accident rate is reduced by approximately 75% compared to the early 1980s.

Finally, comparing the HEMS risks to other occupations is very difficult due to the relatively small size of the "population" at risk. Looking strictly at the numbers, HEMS appears to have a significantly higher death rate than other occupations or causes of accidental death. Only heart disease and cancer have a higher fatality rate when compared to the 22-year average fatality rate for HEMS.

HEMS accidents are not caused by a single event, but by a chain of events. In most accidents, numerous risk factors can be identified. Acting on any of these risks and breaking the chain at any point may prevent an accident from occurring. The United States Aircraft Insurance Group (USAIG) has concluded that complacency is a factor in over 50% of all helicopter accidents. No one can afford to take a passive role in HEMS. The safety of flight requires the right attitude and active participation. Every pilot, mechanic, medical crewmember, communication specialist, and administrator must be fully knowledgeable of

their role and responsibilities. Each must be committed to a safe operation and to ongoing risk management. To fly safe, a program must fly smart. Nothing takes the place of comprehensive training, proficiency, and sound judgment. An important training component should be Air Medical Resource Management. The goal of AMRM is to improve crew communications and interactions by addressing teamwork, communication skills, decision making, workload management, situational awareness, preparation and planning, cockpit distractions, and stress management. The focus of the team must be on doing “what is right” rather than on “who is right.”

The risks in HEMS cannot be underestimated. In addition, the cumulative effects of multiple risk factors must be

considered when making decisions on each and every transport. Risk management is a major component of the decision-making process. It relies on situational awareness, problem recognition, and exercising good judgment to reduce risks associated with each flight.

In the Forum section of the September/October 2001 *Air Medical Journal*, Ed MacDonald, the President of NEMSPA wrote about “the next accident”. This article should be required reading for everyone in HEMS. It addresses the “it can’t happen here” mentality and suggests why *it can happen to you*.

Tragically, there will be a next accident and more of our colleagues will lose their lives. Maybe not today, maybe not this month, or even this year. Hopefully, not

for a long, long time. No one expects it and everyone assumes the next accident will involve someone else’s program.

No one can eliminate the risks related to HEMS. Some may choose to avoid the risk. Programs may close and individuals may decide to pursue a different occupation. Others may choose to influence risk. Organizational culture can influence risk as much as any/all other factors. The cultures, in this case, represent the collective beliefs that shape behavior toward safety and a safe HEMS program. Working together, every member of a flight program must play a role to actively manage risk and to avoid taking unnecessary risk. Your safety demands it. Lives depend upon it.

Do whatever it takes. Don’t be the next accident!

Acknowledgements

Nearly two years ago, the UCAN Safety Committee undertook a simple task to review a few articles pertaining to air medical accidents. Our Section Chief of Emergency Medicine, Dr. James Walter had challenged us for answers regarding the magnitude of risk in HEMS. Did we as a Safety Committee, flight program, or industry have enough information to fully appreciate the safety concerns and risks encountered every day? We decided to meet his challenge head on. Within a short time, this safety report took on a life of its own and our investigation and research were underway.

There are a great many people who participated and helped complete this project. My thanks to the entire UCAN Safety Committee for their dedication to this study and for enduring the endless revisions, additions, and various deadlines. I am also grateful to the entire UCAN crew and the Emergency Medicine faculty who encouraged us as we worked through the various phases of the project. Numerous individuals, operators and aircraft manufacturers shared database information that made our calculations possible. Without the endorsement of the AMPA Board of Directors and Pat Petersen, this report would never have been published in this format and in its entirety. The immediate response and support from Madeleine Byers (CJ Systems) and Sandy Kinkade (Bell Helicopter) further strengthened our resolve to pursue this publication and to obtain the necessary funding to make this document available to the entire air medical community.

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And finally, to Jane, Maddy and Jake. Thank you for putting up with the long hours needed to complete this project. Now, more than ever, I appreciate and understand the importance of putting “safety above all”—for myself, for my crew, for my colleagues. For my family.

—Ira Blumen

Attachment 1: HEMS Accident Summary, 1998-2002

Date Time	Aircraft N Number	Program	City, State	Mission Type	Phase	Phase of flight	Pt	Injuries	Day / Night	Weather	Fire	Aircraft Status	Operator	Comments / Description / NTSB Probable Cause(s)
1/11/98 @ 2250	222UT N222UH	AIRMED	Salt Lake City, UT	ONS	POB	CRU	1	4F	Night	Snow, wind >35mph	PIF	Destroyed	Air Methods	Storm front moving in, wind gusts exceeding 35 mph. Fatalities: 3 crewmembers and 1 patient. NTSB Final: Pilot Error.
3/23/98 @ 0740	205A-1 N90230	Los Angeles City Fir Air Ops Unit 8060	Los Angeles, CA	ONS	POB	TKF	1	4F, 2S	Day	Clear, calm winds 20 mile vis.	Unk	Destroyed	Public	Enroute to MVA and during transport to LA Children's Hospital, pilot reported inflight emergency. Fatalities: 3 crew, 1 patient. NTSB Preliminary: Separation of tail rotor blades and 90-degree gearbox during cruise flight
5/24/98 @ 1235	206 L-3 N27AE	Air Evac EMS	West Plains, MO	INT	PGT	TKF	0	3S	Day	Clear	No	Destroyed	Air Evac EMS	Aircraft lost power during take off at ~ 60 ft altitude and low air speed. Hard landing into parking lot, main rotor blade struck light pole and aircraft rolled onto its right side. NTSB Final: Improper maintenance. Engine's accessory gearbox was improperly assembled, reducing oil flow to the turbine shafting, leading to a total loss of engine power.
6/5/98 @ 0549	350BA N911VA	Valley Air Care	Hartingen, TX	ONS	PGT	CRU	0	3F	Night	5 miles, broken ceiling at 1,400 ft; Grnd fog	PIF	Destroyed	Tex-Air	En route to a rural scene, the helicopter crashed 19 miles past the accident site. Impacted trees and terrain. Visibility severely restricted by thick smoke from fires in Mexico. NTSB Final: Pilot error. Continued flight into adverse weather conditions resulting in a loss of control due to spatial disorientation.
7/29/98 @ 2248	222B N911RA	SkyLife of Central CA	Fresno, CA	ONS	PGT	LNG	0	3N	Night	Not a factor	No	Significant	Rogers Helicopter	While landing at scene of accident, encountered significant blowing dirt and dust ~ 5 ft from ground, resulting in loss of ground reference. Helicopter rolled to its left, landing on its top. Crew was extricated with assistance, but was uninjured. NTSB Final: Pilot error.
8/20/98 @ 2114	222 SP N30SV	Intensive Air	Sioux Falls, SD	INT	PGT	CRU	0	3F	Night	VMC 10 miles; 8,500 ft overcast; winds 12 knots, to 26 gust	PIF	Destroyed	RMH	Enroute to pick up a patient. Routine radio contacts up to 5 min out. At ~2125, comm center received a call from Spencer Hospital informing them that the helicopter had not arrived. NTSB Final: Mechanical failure. In-flight break-up traveling at about 130 knots at 960 ft above the ground. A fatigue crack of the swashplate outer ring pin of the main rotor assembly resulted in the separation of the pin, and ultimately the in-flight breakup.
8/28/98 @ 1053	BK-117 N230H	Topeka Lifestar	Topeka, KS	MAT		LNG	0	3N	Day	Not a factor	No	Significant	St. Louis Helicopters	Returning from 2 days of maintenance at an altitude of 300-400 ft, pilot heard a "loud bang" followed by the aircraft rotating to the right. Pilot was able to touch down upright then the aircraft rolled onto its left side. NOT COUNTED IN TOTALS. NTSB Final: Pilot error. Pilot failed to assure the engine cowling was secured, resulting in the cowling separating from the helicopter and damaging the main rotor and tail rotor.
11/29/98 @ 1756	MD-900 N977LF	LifeFlight	Boise, ID	ONS	POB	TKF	1	4N	Dusk to Dark	Over-Cast 10mi vis	No	No Wind-screen and main rotor blades	Idaho Helicopters	Departing from MVA in a remote canyon, aircraft struck and severed unmarked power lines 150 ft above the ground. Pilot then determined that the helicopter was controllable and displayed no unusual flight characteristics, and chose to proceed to his destination. Aircraft completed mission and landed uneventfully at hospital with patient and crew. Post-flight examination revealed crazing of the windscreens and damage to 4 of the 5 main rotor blades requiring major repair/replacement. NTSB Final: Pilot error.

Date Time	Aircraft N Number	Program	City, State	Mission Type	Phase	Phase of flight	Pt	Injuries	Day / Night	Weather	Fire	Aircraft Status	Operator	Comments / Description / NTSB Probable Cause(s)
12/13/98 @ 1745	AS 350-BA N911MV	Shannon Medivac One	San Antonio, TX	MAT		HOV	0	2N		Clear		Substantial	Southwest Helicopters	Instructor pilot (PIC) had been doing a 3-hr check ride with new pilot, with last maneuver "hydraulics off". PIC then initiated a normal takeoff (with hydraulics 'ON') and during the takeoff, the helicopter rolled over to the left. PIC reported it felt like a complete hydraulics failure. Rotor blades struck the ground, knocking tail nearly off, front of the aircraft was destroyed. NTSB Final: Undetermined.
2/12/99 @ 1720	AS 355 N355MF	LifeFlight	Toledo, OH	INT	PRF	LNG	0	3S	Night	IMC - Scattered snow squalls.	No	Destroyed	CJL	Flight aborted twice due to weather enroute to referring hospital. Pilot attempted a precautionary landing in decreased visibility. Aircraft struck tree and house 1.5 miles from hospital. NTSB Final: Pilot error. Inadvertent flight into IMC, subsequent spatial disorientation and loss of control; also inaccurate weather forecast.
2/13/99 @ 1645	BK-117 B-1 N220H	Hermann Life Flight	Houston, TX	ONS	POB	CLB	2	5N	Day	Clear	No	Substantial	Own Part 135	2-helicopter scene. During approach for landing approach, the pilot noticed power lines running parallel to the road but did not consider them to be a hazard. On take-off, the helicopter hit the power lines and the pilot landed the helicopter in an adjacent field. Undersides of the main rotor blades were damaged and 2 tail rotor blades were destroyed. NTSB Final: Pilot error. Failure to maintain clearance from power lines. Sun glare was a factor.
4/3/99 @ 2350	BO-105 N105HH	Flight for Life	Las Vegas, NV	INT	PRF	CRU	0	3F	Night	IMC Snowing	PIF	Destroyed	Metro Aviation	Helicopter crashed as they were returning to a remote base after delivering a patient to Valley Hospital Medical Center. NTSB Final: Pilot error. Continued VFR flight in deteriorating IFR conditions resulting in spatial disorientation and subsequent loss of control.
4/11/99 @ 1645	BK-117 N163BK	Bay Flight	St. Petersburg, FL	ONS	PGT	HOV	0	3N	Day	Clear	No	Significant	RMH	While lifting off and hovering, tail rotor struck hangar. Tail rotor and skids damaged. Damage to building. NTSB Final: Pilot error. Failure to maintain visual separation with building.
5/15/99 @ 2122	222JT N781SA	Lifeline	Rockford, IL	ONS	PGT	APP	0	3N	Night	4000 ft ceiling, 4mi vis.	No	Substantial	Air Methods	On approach to scene in rural area, hard landing occurred into field. Damage to skids, tail boom and nose cowling. NTSB Final: Pilot error. Misjudged flare during landing.
6/14/99 @ 2208	S-76A N2743E	University of Kentucky	Lexington KY	OTH	N/A	CRU	0	4F	Night	IMC Fog; < 1/4 mile visibility; Winds calm	No	Destroyed	PHI	IFR flight, 2 pilot aircraft. Relocation flight from remote airport (1381' ft MSL) base back to hospital. After take-off, at about 1600 feet, the co-pilot (SIC) who was flying, began a descending left turn and subsequently crashed into rising terrain on a tree-covered slope at ~ 1,000 ft elevation. NTSB Final: Pilot error. Failure of the PIC to adequately supervise the SIC, and maintain a positive climb.
7/17/99 @ 1231	BK-117 N110HH	Hermann LifeFlight	Houston, TX	INT	PGT	CRU	0	3F	Day	Rain in the area	No	Destroyed	Own Part 135	Helicopter was on approach to an intermediate refueling site during an interhospital transfer. A witness saw pieces of the main rotor system separate from the helicopter before the crash. NTSB Final: Mechanical failure. Corrosion of the tension-torsion strap resulting in fatigue cracking and subsequent separation of the strap and main rotor blade from the helicopter.
8/10/99 @ 1138	206L N810F	LifeBeat Air Medical	Cape Girardeau, MO	INT	PGT	TKF	0	3N	Day	N/A	No	Substantial	St. Louis Helicopter	A back-up helicopter was in service. Upon takeoff, reaching the edge of a rooftop hospital helipad, the aircraft did an abrupt and violet yaw to the left, the nose tucked downward and the aircraft started losing clearance. Pilot landed the aircraft on the paved street below, but the tailboom hit a brick wall. NTSB Final: Pilot error. Inadequate preflight planning / preparation — auxiliary power unit cord was attached to the helicopter during the helicopter's takeoff attempt.

Date Time	Aircraft N Number	Program	City, State	Mission Type	Phase	Phase of flight	Pt	Injuries	Day / Night	Weather	Fire	Aircraft Status	Operator	Comments / Description / NTSB Probable Cause(s)
9/10/99 @ 0314	B0-105 N911HR	First Flight	Melbourne, FL	ONS	PGT	APP	0	3S	Night	Foggy	No	Significant	Metro Aviation	Approaching a scene LZ, the helicopter began to descend rapidly from ~ 300 ft. Pilot applied collective control and engine power, but the helicopter continued to descend, colliding with trees and then rolled onto its right side in swampy terrain. NTSB Final: Pilot error. Failure to recognize entry into settling with power during approach to land and failure to take remedial action to escape from settling with power.
11/17/99 @ 1350	206L-1 N519EH	Mercy Flight/ Medflight	Great Falls, MT	ONS	POB	TKF	1	4N	Day	Wind gusts to 15 knots	No	Substantial	Omni-flight	Helicopter responded to a ski resort, with the LZ in an open area near ski lift towers. On take-off, with trees directly in front, the pilot decided to turn the helicopter to the left, hover to an open area and depart downslope. . . . After the helicopter moved left 20-30 ft, the pilot felt the tail of the helicopter "rotate abruptly left." Pilot tried to maintain control and return to the LZ, but the tail rotor struck a lift tower. Helicopter landed hard. NTSB Final: Pilot error. Clearance from an object was not maintained. Gusting wind conditions was a factor.
02/26/00 @ 0200	412 N411UT	LifeStar	Knoxville, TN	ONS	PGT	MAN	0	3N	Night	Clear Night	No	Significant	Own Part 135	Aircraft had arrived on scene and was repositioning in the LZ due to presence of a steep slope. The tail rotor struck a small tree while maneuvering. After contact, the TR and TR gearbox separated from the aircraft. Flying debris from separating components caused further damage to aircraft fuselage. NTSB Final: Pilot error. Failure to maintain visual lookout resulting in collision with tree.
3/10/00 @ 0605	B0-105 N335T	Lifestar	Amarillo, TX	ONS	POB	CRU	1	4F	Night	Fog	PIF	Destroyed	Temco	Responded to a scene reportedly close to the TX/OK state line. Fog reported forming while the aircraft was on scene. The pilot and crew lifted with a patient on board at ~0605. No radio communication was established after lift-off. Due to fog in the area, wreckage was not found until ~1100 hrs. NTSB Final: Pilot error. Failure to maintain control of aircraft as a result of continued flight into known adverse weather. Factors include dark night conditions, fog, low ceiling, and pilot's lack of total instrument flight time.
4/14/00 @ 1610	222 N225LL	Lifelink III	St. Paul, MN	OTH	PRF	CRU	0	2N	Day	Clear	No	Significant	Air Method	During cruise, pilot lost control of aircraft and landed on a two story building. Major damage to skids. No injuries. NTSB Final: Mechanical. Pylon mounted support assembly separated from transmission case due to fatigue failure of the threaded studs and dowel pins, resulting in failure of the flight control system; also, inadequate maintenance procedures by company maintenance personnel.
4/25/00 @ 1215	BK117 N428MB	Bayflight	St. Petersburg, FL	INT	PRF	CRU	0	3F	Day	Not a Factor	No	Destroyed	RMH	Crew had dropped off a patient at Bayfront Medical Center. Departed for base (8 min flight), flying a new route in response to noise complaints from neighbors along the previously direct route. 3-4 min into flight, collided with the radio transmission tower guy wire and the steel tower 480 feet above the ground. NTSB Final: Pilot error. Failure to maintain clearance with tower resulting in collision.
5/6/00 @ 2335	BK 117 N911NC	University Hospital	Cincinnati, OH	FUL	N/A	LNG	0	1N	Night	VMC	No	Substantial	PHI	After crossing the edge of the LZ and almost in a hover, he heard a loud noise or bang from the rear of the helicopter. Simultaneously, the left rudder pedal pushed rearward, and the nose started to move to the right. Pilot made a hard landing. NTSB Final: Pilot error. Misjudgment of closure rate resulting in collision with building. Factors involved: tailwind and stuck windsock.

Date Time	Aircraft N Number	Program	City, State	Mission Type	Mission Phase	Phase of flight	Pt	Injuries	Day / Night	Weather	Fire	Aircraft Status	Operator	Comments / Description / NTSB Probable Cause(s)
7/16/00 @ 0140	BK 117 N312LS	Life Star (Texas)	Allen, TX	ONS	PGT	LNG	0	3N	Night	Not a factor	No	Destroyed	Omni-flight	While maneuvering aircraft at an LZ of a scene response, the tail rotor struck a tree. NTSB Final: Pilot error. Failure to maintain obstacle clearance while hovering.
7/24/00 @ 0230	A Star N911AM	Georgia Baptist Life Flight	Atlanta, GA	INT	PRF	CRU	0	3F	Night	Clear	No	Destroyed	Critical Care Med-flight	Aircraft was returning from a call in Sylvester, GA. Radio contact was lost at 0230. There was no Mayday or distress signal. The aircraft was found in a wooded area. NTSB Final: Pilot error. Pilot experienced spatial disorientation resulting in loss of control of aircraft. Factors involved: dark night light conditions.
7/28/00 @ 1140	222 UT N224LL	Life Link III	Minneapolis, MN	UNK	N/A	TKF	0	1N	Day	Clear	No	Substantial	Air Methods	On liftoff from the helipad, the tail rotor hit the pad light. The pilot landed and shut down the helicopter. NTSB Final: Pilot error. Inadequate preflight, improper vertical takeoff, and not obtaining clearance from helipad light. Factors involved: tailwind takeoff, helipad light.
10/16/00 @ 2355	AS355 N355DU	Duke Life Flight	Durham, NC	INT		CRU	0	1F	Night	Clear	UNK	Destroyed	CJl	Enroute to hospital, the main rotor gearbox (MGB) oil pressure warning light illuminated. After landing the crew went by ground. Mechanic believed the oil pressure switch had failed and disconnected the wire. The pilot did a run-up and hover. The AC then took off and was reported down 16 minutes later. NTSB Final: Mechanical. Failure to comply with manufacturer's instructions for correcting illuminated main rotor gearbox oil pressure warning light, resulting in failure of the main rotor gearbox due to oil starvation, loss of main rotor RPM, and an uncontrolled descent.
10/14/00 @ 1227	206 L N2233F	Classic Lifeguard III	Jacob Lake, AZ	ONS	POB	TKF	1	4M	Day	Not a factor	No	Destroyed	Ovwn Part 135	On takeoff from scene, hit trees. Possible loss of tail rotor effectiveness. NTSB Final: Pilot error. In-flight loss of control during lift-off due to improper planning and decisions. Factors involved: high-density altitude, helicopter weight, and lack of suitable take-off area.
11/13/00 @ 2048	BO 105 911VH	Flight for Life	Pahrump, NV	ONS	PGT	LNG	0	3N	Night	Not a factor	No	Substantial	Metro Aviation	Responding to scene. 2 feet off the ground ready to land when a vehicle entered its LZ. The pilot was about to ascend when he noticed a set of power lines in his path. He powered up to turn around when his skid hit the ground and the helicopter landed on its side. Pilot was able to climb out, crew had to be "cut out". NTSB Fact finding document.
12/18/00 @ 1530	365 N1 N89SM	None	West Mifflin, PA	MAT			0	3M	Day	Not a factor	No	Destroyed	CJl	Tail rotor control loss during post-500 hr maintenance operation check. Several attempts were made to land. On the last attempt the pilot lost control and executed a controlled crash landing. NOT COUNTED IN TOTALS.
12/22/00 @ 0331	206 N288JB	Critical Air Medicine	Wilcox, AZ	INT	PRF	LNG	0	3M	Night	Not a factor	No	Substantial	Critical Air Med	Pilot experienced sudden onset of illness due to apparent food poisoning. A very hard landing was made at Wilcox Airport. NTSB Final: Pilot incapacitation. Due to nausea. Pilot collapsed onto cyclic causing inadvertent main rotor contact with ground.
01/22/01 @ 0005	206 L-1 N61AE	Air Evac	Quincy, IL	INT	PGT	TKF	0	1F on ground 2N	Night	Clear	No	Minor	Air Evac EMS Inc.	Hospital security officer walked underneath the tail boom while the AC was running. The officer was struck in the head by the tail rotor resulting in a fatal wound. NTSB Final: Ground crew error. Security guard failed to maintain clearance from tail rotor.

Date Time	Aircraft N Number	Program	City, State	Mission Type	Phase of flight	Pt	Injuries	Day / Night	Weather	Fire	Aircraft Status	Operator	Comments / Description / NTSB Probable Cause(s)
02/28/01 @ 1024	412 N412SM	St. Mary's Air Life	Grand Junction, CO	MAT		0	1F	Day	Not a factor	No	Destroyed	PHI	Departed the hospital helipad for post maintenance test flight that required autorotation. Impacted the ground approximately 24 minutes later, 11 miles south of Grand Junction. NTSB Final: Pilot Error. Pilot failed to maintain rotor speed during an intentional autorotation, resulted in a loss of control.
03/23/01 @ 1320	206L1 N2138Y	EMS Air Services of NY	Seneca Falls, NY	UNK	CRU	0	2S	Day	Not a factor	No	Substantial	EMS Air Services of NY	Pilot heard bangs and experienced yawing and power loss. He determined that tail rotor thrust was lost. Upon precautionary landing the aircraft rolled. NTSB Final: Mechanical. The loss of a bolt in a Thomas coupling on the tail rotor drive shaft, for undetermined reasons, during climb, while operating over unsuitable terrain.
04/06/01 @ 1715	222UT N222LF	Wyoming Life Flight	Alcova, WY	ONS	PGT	0	3N	Day	Not a factor	No	Substantial	CJ Systems	In hover, pilot attempted to reorient aircraft when the tail rotor struck a 55-gallon barrel. Aircraft landed with damage. NTSB Final: Pilot Error.
04/23/01 @ 1430	206L3 N215M	Critical Air Medicine	Phoenix, AZ	INT	CRU		3N	Day	Clear	No	Substantial	Critical Air Medicine	Aircraft experienced total power loss and pilot completed an autorotation landing. NTSB preliminary.
05/05/01 @ 1700	BO-105C N105RH	Mercy Flight	Medford, OR	INT	POB	1	4N	Day	Not a factor	INF	Substantial	Own 135	Power loss and fire in #1 engine. Emergency landing at airport and fire extinguished by airport personnel. NTSB preliminary.
06/03/01 @ 1620	369D N1109V		Hanapepe, HI	ONS	PGT	0	4N	Day	Not a factor	No	Substantial	Smokey Mountain Helicopters	Not dedicated EMS. Enroute with firefighters to pick up a "medical emergency" and experienced engine failure. Autorotated into trees. NTSB preliminary. NOT INCLUDED IN TOTALS.
07/20/01 @ 1603	BK117 N313LS	North Texas LifeStar	Addison, TX	INT	PGT	0	2S 1M	Night	Clear	NO	Substantial	Omni-flight	While enroute an engine failed. While turning towards the airport the 2nd. Engine failed. The AC crashed. NTSB Final: Pilot Error. Failure to follow preflight checklist and turn on fuel pumps resulting in fuel starvation and power loss.
07/21/01 @ 0049	S-76 N769BB		Los Angeles, CA				1M	Night	Not a factor	No	Substantial	Helinet Aviation	Had transported an organ harvest team to hospital. Helicopter rolled onto its right side while standing unmanned with both engines operating and rotors turning. NTSB Fact. NOT INCLUDED IN TOTALS.
08/18/01 @ 1425	355F1 N53LH	Care Flight	Reno, NV	ONS	POB	1	4N	Day	Clear	No	Substantial	RMH	Pilot lost visual reference upon takeoff from accident scene (brown out). Attempted to land and aircraft rolled over. NTSB Final: Pilot Error. Selection of unsuitable landing zone.
09/22/01 @ 2006	AS350 N911NT	Enloe Medical Center	Chico, CA	ONS	PGT	0	1F 1S 1N	Night	Clear	No	Destroyed	Enloe Medical Center	Approaching scene LZ with flight nurse using night vision goggles. Encountered brown out and aborted landing. Impacted trees and crashed. NTSB preliminary.
10/07/01 @ 2250	AS355F1 N911BB	Southwest Helicopters, Inc.	Rosebud, TX	ONS	PGT	0	2M 1N	Night	Clear	No	Destroyed	Southwest Helicopters, Inc.	Difficulty finding scene and crew informed pt. to be taken by ground transport. Both engines lost power and pilot initiated autorotation resulting in a hard landing and slide. Aircraft separated from skids and came to rest on its side. Fuel system found to have a total of 2 quarts of fuel. NTSB preliminary.
10/19/01 @ 1458	350B2 N111DT	Med Air	Roswell, NM	PR	N/A	0	2F 2S	Day	Not a factor	UNK	Destroyed	Medical Air Transport	LZ training. 2 police officers killed, pilot and another police officer serious. NTSB preliminary.

Date Time	Aircraft N Number	Program	City, State	Mission Type	Mission Phase	Phase of flight	Pt	Injuries	Day / Night	Weather	Fire	Aircraft Status	Operator	Comments / Description / NTSB Probable Cause(s)
11/09/01 @ 1445	A119 N119RX	IHC Life Flight	Ogden, UT	INT	N/A	APP	0	2M	Day	Clear	No	Significant	Own Part 135	Upon approach, rotor RPM decayed and did not recover. Hard landing and skids torn off and aircraft rolled onto side. Flight was for a survey of new helipad. NTSB Final: Mechanical. Improper rigging of the rotary variable differential transformer by the manufacturer, resulting in incorrect fuel scheduling to the fuel control unit.
11/14/01 @ 0033	BO-105 N93LF	Bannock Life Flight	Pocatello, ID	MAT	N/A	CRU	0	1S	Night	Not a factor	PIF	Destroyed	Own Part 135	Pilot landed as a precaution secondary to fuel transfer pump problem. Medical crew and patient went by ground. Mechanic arrived 5 hours later to repair aircraft. Pilot took off and was returning to base and experienced decreased visibility and crashed. The mechanic saw "a bright glow" and followed the flight path of the aircraft. The mechanic extinguished the fire, disconnected the battery, and called for help. NTSB Final: Pilot error. Failure to maintain adequate clearance of terrain during initial climb.
01/18/02 @ 0025	BK 117 N626ME	University Hospitals MedEvac	Cleveland, OH	OTH	PGT	TKF	0	2F 1S	Night	Not a factor	UNK	Destroyed	CJ Systems	AC lifting from rooftop helipad when it struck side of hospital and crashed to ground. NTSB preliminary.
01/20/02 @ 0750	109 N55NW	Airlift Northwest	Seattle, WA	ONS	PGT	TKO	0	1S	Day	Light Rain 3000 ft. ceiling	No	Significant	CJ Systems	Power loss shortly after takeoff necessitating emergency landing from altitude of approx. 300 ft. Initial return flight aborted due to weather. Attempted to return to base the following day when crash occurred. NTSB preliminary.
03/21/02 @ 1335	AS-350B N1184H	Mountain Life Flight	Susanville, CA	OTH	PRF	CRU	0	1F 2S	Day	Not a factor	No	Substantial	Mountain Life Flight	AC returning to base and collided with the surface of lake. NTSB preliminary.
6/21/02 @ 1207	AS-350-B2 N852HW	LifeNet	Norfolk, NE	INT	PGT	CLB	0	3F	Day	VFR	No	Destroyed	RMH	Pilot informed dispatcher of a "pedal binding in the right pedal." At 50 to 100 feet AGL aircraft "started spinning and descending until the nose dropped and the helicopter impacted the terrain." NTSB preliminary.
09/07/02 @ 0428	222UT N417MA	Mercy Air Services	Nipton, CA	ONS	PGT	CRU	0	3F	N	VFR	PIF	Destroyed	Mercy Air	En route to accident scene. Witnesses reported aircraft was "flying low and very fast" and impacted the ground nose-low. Post-impact fire occurred. No distress call or problems reported. NTSB preliminary.
09/09/02 @ 2152	206 N400SL	Careflight	Sioux Falls, SD	INT	POB	UNK	1	4F	N	UNK	UNK	Destroyed	Omni-flight	Aircraft was enroute to Sioux Falls, SD. Last position report was at 21:58. Aircraft was found by farmers in a soybean field at approximately 0930 (9/10/02), not far from last position report. There was no distress call. NTSB preliminary.

Key:

Mission Type		Mission Phase		Phase of Flight				Injuries		Fire	
FUL Refueling	PR Public Relations	PGT Going to get the patient	APP Approach	DEC Descent	MAN Maneuvering	N None	INF In Flight				
INT Interhospital	TNG Training	POB Patient on Board	CLB Climb	HOV Hover	TKF Takeoff	M Minor	No No Fire				
MAT Maintenance	OTH Other	PRF Returning from patient	CRU Cruise	LNG Landing	TXG Taxiing	S Serious	PIF Post-Impact Fire				
ONS Onscene						F Fatal	UNK Unknown				

Sources: LeRoy Jackson, Air Methods; Connie Schneider, Fitch and Associates; CONCERN Network; NTSB Aviation Accident Synopses, <<http://www.ntsb.gov>> and Preliminary Helicopter Accident Reports, <<http://safecopter.arc.nasa.gov>>.

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EDITORIAL COMMENTS

RISK MANAGEMENT, BENEFITS AND COST

Dr. Blumen kindly asked me if I would comment on this penetrating and in-depth report. As someone who has never been shy about offering an opinion about EMS safety, I welcomed this opportunity to contribute as one who has loved this avocation for many years. First, I would like to commend Ira and the UCAN Safety Committee for this thorough and comprehensive labor of love. Much time and energy has gone into this effort and I hope it may change the way we look at EMS aviation safety evermore.

“Consensus is that the current EMS helicopter safety record is appalling. Unfortunately, that is the only consensus among the various participants. There is not even agreement about what constitutes an EMS accident. In 1986, for example, one can cite from reputable sources that there were 16 EMS accidents (*Hospital Aviation Magazine*), or 22 (*American Medical News*), or 28 as reported by CBS television’s *Sixty Minutes* or *Helicopter News*, or 14 or 17, as reported by the FAA in two separate forums. Similarly, the number of EMS helicopter fatalities has been variously reported as 13, 15, 19, 21, and 25.”¹ This is from an article by Ira Rimson, written in the National EMS Pilots Association’s *Air Net* in 1987. Reporting methodology continues as a problem for statistical purists even today. We do, however, continue to see the same type of accidents with the same persistent causes as years past. Whether or not statistics indicate a trend or a community-wide problem does not override the fact that one (preventable) accident is too many.

Although this report attempts to collate all available information concerning EMS Aviation Safety or occasional lack thereof, quantifying EMS aviation operations and accidents has been imprecise, to say the least. Although the numbers and underlying causes have been a challenge to decipher due to inconsistent methods for classifying EMS accidents, incidents, forced, precautionary, and hard landings, we still can draw valid and helpful information as to the risks involved. The statistics at a macro level

are important—but management of the risks happens at a local program and personal level. It is important not to get too wrapped around global statistics and get more concerned about managing safety at the level we can truly affect. As A. E. Housman states, “Statistics in the hands of an engineer are like a lamppost to a drunk—they’re used more for support than illumination.” I would recommend that you take all of these studies and boil them down to something usable at your base. A local risk assessment, based on the hard, cold lessons of others, may help you look more honestly at yourself. If you derive nothing worthwhile from this entire study or believe that it only happens to someone else, you may wish to look into the mirror for the problem.

Probably the first civilian EMS accident in this country occurred in May 1978 in an Alouette and its cause was reported as mechanical and engine-related. That was not, however, where an early underlying cause for EMS accidents was born. If we only look into accidents from the civilian sector of EMS we will miss some valuable clues to some very basic risks and causes of EMS accidents. Critical patients were being flown long before the first hospital-based program began in Colorado in 1972. As early as 1970, military air ambulance organizations returning from Viet Nam were beginning the Military Assistance to Safety and Traffic program (MAST). Helicopters had been extensively used to transport the wounded, sick, and injured in the Korean and Viet Nam wars and as far back as Burma.

The MAST program utilized military aeromedical assets and personnel to provide much needed assistance to the civilian sector. Military air ambulances began to provide emergency transportation of sick and injured from the streets and highways in several states. By the late seventies, more than two dozen locations throughout the nation were served by military emergency aviation services. The entire EMS arena in the United States was beginning its transition into the sophisticated and responsive systems we

see today. The MAST program was a critical link in the system’s genesis as well as a model for EMS aviation in the civilian sector. The MAST program also suffered from some of the similar stressors that have carried over to today’s EMS aviation cultures. Pilots who risked their lives evacuating their fellow soldiers from the mountains and rice paddies of Viet Nam were now being asked to do the same for their fellow citizens on the farms, highways, and mountains of the United States. This ingrained noble and very human drive, which perhaps could be termed “the rescuer ethic,” still compels much of what we do and feel today.

Having served in this avocation as both a military and civilian EMS pilot, it is a pressure that one feels every time the tones go off. It is why many of us do this work. It is the adrenaline jolt that drives us to do great things. It drives us into taking risks. It occasionally pushes us to take foolish risks and go beyond our best judgment. Sometimes that risk-taking pushes us beyond recovery. There is a time for heroes, but whether or not that is a risk we can really accept needs to be addressed directly with each member of an air medical team, management, and the communities we serve.

This underlying ethic is one common to the dispatchers, pilots, nurses, paramedics, physicians, program managers, policemen, firemen, and almost everyone involved in the emergency and public safety field. To deny that the “rescuer or hero mentality” exists is to somehow deny who we are or who we want to be. It is also something that rarely appears on an EMS aircraft accident report. It is difficult to quantify and a bigger challenge to manage. It is the “elephant in the road” that no one readily admits to. It is a very real characteristic that drives us to do what we do—yet is seldom addressed as a core value or accident cause.

Every time I read an accident report where the pilot and crew perish in a blinding snowstorm, foggy meadow, driving thunderstorm, or pitch-black hillside I always ask, “What were they doing there?” “Why didn’t they turn back?”

“Why did they go at all?” Often as not, the team is on their way home or transferring a relatively stable patient who might as easily been transferred by ground ambulance or waited a few hours in their hospital room. Combine the *hero mentality* with *get-homeitis* and we have a deadly mix. Look at the statistics throughout this report and you will see some of the catastrophic results of pilots and crews unnecessarily flying into deteriorating weather conditions or pushing well beyond their personal limits. Most helicopter operators train their pilots to have a corporate, professional mentality. That is a good start. We cannot deny that there are many pressures on an EMS pilot that bring the “rescuer mentality” to the surface. How we as an EMS community deal with this intense drive to help others is a topic that the EMS aviation community must openly and regularly discuss. A written policy is just eye-wash and falls far short of effective risk management.

If we look at NTSB accident reports and accept them at face value, we will be limited in truly understanding the core values that really created the accidents. In those reports we will find that “the pilot flew into a hill, hit wires or buildings, or disregarded regulations or company policies and procedures.” Those are real causal elements—but simply do not go deep enough. We must understand the organizational culture and personal values that drove a pilot into a situation that was needless and preventable.

Human factors remain as the number one cause of EMS accidents. “A study of 87 accidents from 1987 through 2000 found that human error was the primary causal factor in 76 percent. The greatest concentration of human error occurred in the en-route phase of flight and often involved faulty in-flight planning and decision making or inadequate evaluation of weather information.”²

In his 2001 study, Pat Veillette found that “forty-one of the 87 accidents (47%), including 26 of the 32 fatal accidents (81%) occurred during the en-route phase of flight. Of the en-route accidents, 68% resulted from human error.”³ “Twenty-six percent of the accidents—and 53 percent of the fatal accidents—occurred in low-visibility or instrument meteorological conditions.”⁴

In the EMS Line Pilot survey conducted by NEMSPA and HAI in 2000-2001, pilots who flew Emergency Medical Service helicopters reported that management or crew pressure was most often the greatest risk to safety as a whole in the industry. It was closely followed by night operations, inexperience, weather reporting or forecasting, and poor decision making. When asked about factors that have contributed to the rise in EMS accidents, pilots responded with “pushing weather minimums, complacency, lack of IFR training, and inexperience.”⁵

EMS pilots are routinely called upon to launch on a moment’s notice, day or night, 24/7, to unprepared landing zones with marginal weather reporting for their destination(s) and routes. This substantially raises the risk over that of the average commercial pilot who is able to fly from approved airport to approved airport with adequate planning time and official weather reporting. Throw in a palatable sense of urgency and the stage is set.

The *Air Medical Accident Analysis* report, conducted by the subcommittee resulting from the April 2000 Air Medical Summit, performed a thorough study of 20 air medical accidents that occurred from 1993 through 2000. As background, this report stated: “Between 1987 and 1997, there were on average four air medical helicopter accidents per year for the industry. By 1997, the accident rate for AMS (Air Medical Service) operations had been reduced to 1.97 accidents per 100,000 flight hours from a high of 17.08 in 1987. In 1998, however, the number of accidents rose to a nine year high of seven, but more alarming, was the rise of fatalities to fourteen, the highest number since the peak year of 1986. In 1999, the number of accidents rose even higher to ten, the highest also since the peak year of 1986. Fatalities were down to ten but still higher than the average of six.”⁶

We have discussed statistics and safety risks throughout Dr. Blumen’s document. I would like to move our focus to the solutions. Some of these are technological and institutional. I would submit, however, that the real answers are in strong personal and organizational safety cultures enforced by proactive and aware management. Levelheaded professionals

must replace risk takers and adrenalin junkies. Pilots and crewmembers who place safety values below that of personal thrill seeking or a mistaken sense of heroics must change their spots or find new professions. Managers, hospital administrators, accountants, and program directors must insure that their pilots and flight teams have proper tools and facilities to do their jobs safely.

Technology will provide stronger, more dependable, and ergonomically friendly equipment, both in the aircraft that we fly and in the gadgets associated with flight following, air traffic control, terrain avoidance, GPS, night vision equipment, avionics, flight instrumentation, and controls. Many are readily available today. Many flight programs today are using 30-year-old technology, underpowered, or marginally safe aircraft, and expecting their pilot and flight teams to make due. Some programs continue to ask their pilots to fly multiple and dissimilar airframes on a routine basis. Some programs utilize a spare aircraft that is dissimilar or inadequate for the mission. There is a managerial blind eye to the risks that those cost-saving measures create. Often budget constraints and a politically driven decision process exclude the pilot effectively from the aircraft selection process. Occasionally, the RFP process creates a situation where costs take priority over safety. Medical personnel often have the final word in selecting the aircraft and often do so based on medical needs with token regard to the most important tool in the process—the aircraft. There are many aircraft in use today that are missing what I would consider critical elements for an optimum EMS helicopter.

These critical aircraft requirements, in my opinion, are **one** single type aircraft with an adequate margin of power and performance to do any of the missions a program requires in its area of operations. This should account for weather, terrain, and all environmental factors. The aircraft should have adequate avionics, lighting, and safety features. It should have sufficient space, efficient medical configuration, and ergonomics to safely and efficiently treat the type and number of patients to be flown. A single type of helicopter model with similar ergonomics and systems in the program aircraft

reduces risks and maintenance complications as well. Dissimilar aircraft create another obvious risk ignored by many programs and operators. Perhaps there is a sound risk management reason why a Southwest, United, or Delta pilot remains solely on one airframe, type, and model. Aside from the obvious training, standardization, and maintenance advantages, there are very valid and often ignored risk management reasons to keep pilots in only one aircraft type and model. If you've ever rented a car different than the one you drive at home and searched for the parking brake release or windshield wiper button in a dark parking lot or rainy freeway, you should understand the term "negative habit transfer." One question is whether or not thinly stretched community, hospital, or program director's budgets are willing and able to afford that in the future—or even in the present.

The other question is whether or not operators or programs are really willing to take **all** of the steps necessary to aggressively manage risks. Hospital and corporate CFOs who approve budgets must not be lured into false economies that elevate risks. Insurance companies and government agencies are now, or will be, exerting their influence on unsafe, ineffective or redundant programs. The MBA mentalities who believe profits and costs are the only measures of good business must add safety as an equal partner to their thought process. If we want to make a difference in our day-to-day risk management, we must take a hard look at how "that's the way we've always done it" affects us today.

The Air Medical Service Safety Summit's *Air Medical Accident Analysis Final Report*⁷ concluded its study of 20 recent air medical accidents with the following interventions that rated high in both effectiveness and feasibility. They were:

- Enhance the training for night flying operations
- Enhance the training for mountain flying operations
- Equip aircraft with Terrain Avoidance Warning Systems (TAWS)
- Equip aircraft with Radar Altimeters
- Provide aircraft with mission-essential equipment

- Improve the content of weather briefings

The top six in the high effectiveness and moderate feasibility were:

- Conduct/enhance annual IFR proficiency checks
- Conduct/enhance training to improve understanding of weather briefings
- Enhance overall training in recurrent, professional knowledge, etc.
- Conduct/enhance training in Aeronautical Decision Making (ADM)
- Establish integrated and structured Pilot Training Programs
- Conduct/enhance mission-oriented training

This report was distributed to the Air Medical Services subcommittee of HAI, the Air Medical Safety Advisory Committee (AMSAC), and the AAMS/CORE Safety Committee for their review and suggestions. A major key to the training issue is that it should be mission oriented. If the pilot is expected to find and land in an LZ in the mountains on a pitch-black foggy night or land in a dusty or snowy LZ, regular and recurring training should meet that requirement. Unfortunately, many operators routinely train on safe and sterile runways or helipads. If we are to truly lower our risks, we must train in the same environment and mission conditions we will encounter. Instrument training should involve real inadvertent IMC situations under real mission profiles. In the real EMS world, this means that training dollars must come from vendors and programs alike to better manage risks. We have some real solutions. We must have the will as well.

When the EMS line pilots were asked for their suggestions to improve safety in the NEMSPA line pilot survey, the top vote getter was, "Increase quality and frequency of training." This was following closely by "Improve pilots' salaries and benefits," and "Night Vision Goggles." We need to stop ignoring the hard, cold fact that our pilots cannot see like bats in the dark. We have been pretending somehow for years that once you are an EMS pilot, you become magically endowed with built-in sonar and night

vision skills. Pilots and crews must learn to say "no" when asked to perform outside of their limits. The right equipment includes things like night-vision devices, night suns, and skid lighting. If you don't have adequate lighting or NVG assistance, don't use your rotor blades as curb feelers as you plough through a dark night.

Another ominous finding in the NEMSPA/HAI survey was that over 25% of EMS pilots either had not received any crew resource management training or they felt it was ineffective or not well presented⁸. When asked about the effectiveness of their training or preparation for their present position, significant numbers (>10%) of pilots responded that the following areas were weak: Flight crew dynamics or interaction, Crew Resource Management, Aircraft systems, and mission planning.

In response to the need for improving and standardizing Crew Resource Management, the Air Medical Safety Advisory Committee (AMSAC) pushed the development of the Air Medical Resource Management (AMRM) program. Through the efforts of Michelle North, an exportable AMRM package was produced and "Train-the-Trainer" sessions initiated. It is the intention of the AMSAC that it become available to all programs and that they continually train in this invaluable resource.

We should all take heed of one particular result of the EMS pilot survey. *After years of warnings to the EMS aviation community about the need for pilots to make flight go-no go decisions independent of pressure, approximately 20% of pilots surveyed responded that "occasionally, some flight crews do pressure a pilot to launch or continue a mission."* Pilots also responded in significant numbers that they had been pressured to take flights by management and that local competition created some pressure to fly. Pilots were also pressured to speed up launch times creating opportunities to miss critical tasks. Most program managers as well as dispatchers, pilots, and medical crewmembers must control their perceived need to hurry up or pressure pilots. It is clear that some do not. Sometimes our most seasoned medic or nurse is also the most adamant about the "need for speed." Sometimes it is the crewmember who has watched too many

“911” TV shows or has a “Rambo” self-image. These human factors are clearly manageable and these risks avoidable with effective leadership and personal discipline.

The Air Medical Safety Advisory Committee (<http://www.amsac.org/>) “was envisioned to be an operator driven forum dedicated to the sharing and development of safety information and initiatives for the AMS industry.” It is dedicated to seeking solutions to some of the EMS aviation community’s tough issues as they relate to competition, flight and duty time, fatigue countermeasures, standardized criterion for Air Medical Services incident/accident reporting, and other EMS safety issues. The organization continues today with participation from operators, programs, NASA, FAA, insurance, and air medical professional organizations. Ask your operator if they participate. Unfortunately, a few operators have not thought it worth their time and effort.

The bottom line is that there are no new accident causes. If we want to fix what’s broken at a human level we need only to look at Pat Veillette’s chart at Figure 1-21 of this report and see what type of human factors are causing accidents. The top three are “risk taking, pre-flight planning, and in-flight decision making.” We have met the enemy and it is us.

In conclusion, NO pilot should ever have to make critical flight decisions under the thumbscrew of peer pressure, competition, job security, or self-inflicted sense of urgency. If you want a quick barometer of your program’s safety culture ask a few key questions such as:

When was the last time someone from the hospital, vendor, or corporate management attended a program safety meet-

ing, rode along at 2:00 AM, or simply sat down in the crew lounge and chatted with the crews about the things that really matter?

When was the last time you did “hands-on” extrication, survival, or crash drills under realistic mission-oriented profiles?

What percentage of your annual and required training is devoted to the biggest and riskiest tool in your medical kit—the aircraft—or scene safety—or helipad safety—or weather—or Air Medical Resource Management?

Do your aviation maintenance technicians have adequate time, facilities, resources, and full support to do their critical work?

What happens when everybody knows that one of the pilots is a cowboy or is constantly pushing the envelope?

Who picks your monitors, defibrillators, IV kits, or traction splints? Who picks your aircraft?

What happens if a crewmember, flight communicator, manager, or doctor pressures a pilot or crew to fly?

How often do you train the folks who set up your LZs?

What happens if someone says “no” or “let’s go back”?

Can you ask these questions in your organization?

When was the last time you did? Did anything change?

This is hardly a comprehensive list. Each of us should continually and honestly assess our safety attitudes, values, and culture. We don’t need any more heroes and monuments to the tragic end of noble intentions. We need enlightened managers who will be fiercely independent and effective when it comes to safety issues. We need as much priority

on risk management as we have on public relations, charting, medical training, nursing or paramedic or piloting skills.

How do administrators select their program directors or lead pilots? What skill sets does one need to be a manager? Must a program director be a nurse? Are leadership and management skills more important than medical, nursing, aviation, or technical skills for a manager? How much emphasis is there that leaders thoroughly know and use risk management principles? Do present-day EMS program management courses place a high priority on safety and risk management? How long will we continue to do things the way “we’ve always done them”?

We need corporations, programs, and operators who *always* put safety first through action not words. We need manufacturers who will produce aircraft that can do the job. There must be adequate, appropriate, and well-maintained equipment that can do the mission. We need pilots who will participate in the process and have the courage to speak out for safety issues and hold their ground. We need safety cultures that support those who say “no” for safety’s sake. We need the will and the courage to change. “There are three kinds of people: Those who make things happen, those who watch things happen, and those who ask, “What happened?”

—(Casey Stengel)

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- 8 Joint Helicopter Association International/National EMS Pilots Association *Line Pilot Survey*, 2001 <<http://www.nemspa.org/EMS%20Line%20Pilot%20Survey%202001.htm>>

CAN WE HAVE BENEFIT WITHOUT RISK?

We are pleased to contribute to defining a context for the extremely important work being presented by Dr. Ira Blumen and his colleagues at the University of Chicago Aeromedical Network (UCAN).

The passion and commitment of practitioners in air medicine is legendary. Following from the successive military experience in Korea and then Vietnam, helicopter evacuation of the critically injured, often in the most dangerous and trying of circumstances, took on near mythic status. The ethos of “finding a way” came home and into the civilian world of air medicine. Thirty years after the first helicopter program began operation at St. Anthony’s, the debates about value—the interface of benefit, risk, and cost—continues.

In recent months, Thomas and colleagues in Boston have reviewed and published annotations of the best empirical studies for the use of air medical intervention for critically ill and injured patients.^{1,2} In addition, recent studies comparing cost of intervention^{3,4}, increased mortality after program closure⁵, and a cost-benefit analysis of air medicine^{6,7} increasingly support the evidence base for measurable benefits across a wide range of disease and injury processes. Marrying the unique technology of aviation with critical care medicine has not only improved care for the critically ill and injured, but improved access and equity within the healthcare system. But at what cost and is the cost worthwhile? In this case, it is not only the cost of care but also the human cost in lost or impaired lives through aviation accidents.

While the benefits for individual patients and the wider population are demonstrable, it is equally important to understand safety. The issues of aviation misadventure coupled with the Institute of Medicine Report⁸, noting alarming rates of medical misadventure leading to preventable death, must give both patients and providers great pause in assessing safety.

Safety throughout medicine is of great

concern to individual patients, the public, and providers of care. After a single accident recorded in 1996, the air medical community over the past five years has seen an upsurge in the number of aviation accidents and incidents leading to death and serious injury. How safe is this enterprise and do the benefits outweigh the risks? The earliest test of medicine—“first, do no harm”—must be answered.

The short answer is that it is difficult to answer these questions. We have long assumed that benefits outweigh risks while each of us wonders and worries about experiencing an accident firsthand. While the number of accidents has increased, it is impossible to understand if the actual rate is increasing. To measure rates one must have both a numerator and a denominator—in this case the number of accidents measured against exposure—the number of flights and the number of flight hours. Sadly, and frustratingly, it has been nearly impossible to measure and “how safe” remains virtually unknowable.

Competitive pressures between programs, Part 135 Operators, vendors, the lack of central data repository, and the costs of gathering and analyzing data have all played a part in the creation of a contextual black hole as regards the safety of air medicine. Operators, the FAA, NASA, air medical providers, and insurance underwriters have become increasingly frustrated with the current lack of data. While there have been a number of initiatives in the past two years—the creation of the Air Medical Safety Advisory Council (AMSAC) the ASRS program from NASA, the Root Cause Study Group Report, and the accident database from HAI—the overall understanding of risk and safety remains limited. Why is this important? Simply that the absence of good data and analysis is corrosive on many fronts from poor regulation—rules that do not fix problems, to escalating insurance premiums, media alarm, and most worryingly, to increasing distrust on

the part of the public.

The publication of this paper changes the discussion on all fronts. Until this report there has been no real effort to collect or examine the underlying data to truly have any understanding of overall safety and the risks of air medical intervention. Understanding risk is essential for both providers and patients. There are risks throughout medicine and in all ambulance transport, whether by ground or air. The questions each of us must answer in the delivery of any medical intervention and therapy are:

Do we understand the risk and have we taken every step to minimize the risk?, and

Do the benefits outweigh the risks?

This paper by Blumen, et al., is a huge step forward in answering these questions. While the gathered research is still limited by the lack of a central repository, the gathered and compared data from many fronts allows a reasonable set of assumptions to measure risk and safety in air medicine. Stated another way, the real question is: Can we eliminate the medical risk in any given therapy and at what cost to benefit? The answer is no—without at least some risk we would not have benefits.

Most importantly the final sections of the report look at the risk to providers and patients. The news is sobering to providers while good for patients. Without question the issue of risk is tied to exposure. This is a message we must take home. Managing risk—identification, avoidance, reduction, and management are key strategies that each of us must employ every day. Every provider and participant in air medicine should read and re-read this report, take it to heart, and then change your practice.

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ANGELS OF MERCY OR ANGELS OF DEATH

In the late 1980s a television news-magazine referred to the air medical industry as the "Angels of Mercy or Angels of Death" in reaction to the high accident and fatality rate. This rate reached an all-time high of 13.14 accidents per 100,000 hours flown. In contrast, during this same time frame commercial airliners were experiencing a rate of .002/100,000 hours. As this safety report has shown, the accident rates and fatal accident rates per 100,000 flight hours are down dramatically from what we experienced in the mid-'80s. Unfortunately, from 1998 through 2001, we have had more accidents than in any four-year period in HEMS history, including the "death star" years. In addition, the fatal accident rates are the highest they have been since the early 1990s.

What has changed and what has not? We are flying more sophisticated equipment. Oddly enough, during a recent Helicopter Association International Exposition Safety Symposium, a group of helicopter manufacturers conducted a panel discussion on the high accident rate. It was their premise that they [manufacturers] have re-designed, re-engineered, re-structured, automated, and improved the basic flying machines, yet we are crashing at the same, if not higher rate than was experienced prior to all these improvements.

We added more pilots to air medical programs to reduce exposure and fatigue while on duty as fatigue was considered to be a major factor in the accident chain of events. We increased weather minimums in the hopes that standards would encourage better decision making. We formed an accreditation group to promote competition in achieving excellence and professionalism. Associations were formed to provide a forum and infrastructure to attack safety issues head on. The industry was aggressive and came together with

safety as their coat of arms.

The fruits of this labor seemed to provide quite a harvest as 1990 came to a close with no fatalities. Had we nipped the beast in the bud? Unfortunately, we returned to a smattering of accidents in the early and mid-1990s. The number of accidents began to escalate in 1998 and continued through 2001 when we had 13 accidents.

The industry took a deep breath and said, "where do we go from here?" We re-grouped, met in mass, identified seven initiatives to break the chain of accidents and attempted to provide an action plan with which to proceed. The FAA was anxious for our industry to come up with an in-house solution. But did we?

Unfortunately, unilaterally there has been little change in the way we do business. An Air Medical Resource Management course has been developed. Fielding and implementation is slow as financial support for safety education and training is not uniformly endorsed throughout the industry. The Air Medical Safety Advisory Council was formed in the hopes that Part 135 vendors could provide some insight and solutions to industry safety trends and share information to aid in the prevention of repetitive safety infractions.

As in all organizational structures, progress is impeded by the very large geographical nature of our business. There is an underlying sense of "breath holding" until the end of the day in hopes that another significant event [accident] hasn't occurred. And then a new day begins, as do our hopes. We still hear of repercussions for "whistle blowers" on safety issues. Individuals within organizations are afraid to come forward with safety of flight issues for fear of losing their jobs. Aberrant behaviors are sometimes rewarded rather than punished. Between operators there is little

exchange of information for fear of disclosing proprietary issues. Successes as well as failures are not shared. And in these tough financial times in the health-care industry, competition is the dragon in disguise for faulty decision making, cutting safety corners, eliminating safety infrastructures, training and education, and general apathy toward developing a safety culture.

But all is not lost. There are multiple things your organization can do to get on the safety bandwagon and bring the accident rate to zero. This must, however, start at the top with management buy-in that safety is the only imperative to exceed mission accomplishment.

This report may raise your awareness with regard to safety and some unique risk assessments. But safety must be an integral part of everything your program thinks, says, and does. Safety has to become an attitude and a way of life. You don't "get safe" when you come to work. It must permeate the mind-set of your organization. Resources must be committed to safety training and education. Formal safety standards must be set, must be trained, and must be adhered to. Safe behavior should be rewarded and unsafe behavior should have serious consequences. Open communication must be encouraged. And above all, your organization must develop a safety culture that promotes the motto, "if it's not worth doing safely, it's just not worth doing!"

No, all is not lost, but without aggressive, proactive, and committed attention to individual organizational safety infrastructures, the accident rate will not change, and we may be re-crowned Angels of Mercy or Angels of Death.

Michelle North, Ph.D.
President
The Wisdom Well

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