Human Error Associated with Air Medical Transport Accidents in the United States

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Helicopter emergency medical services (HEMS) play a vital and growing role in the U.S. healthcare industry. However, since 1998, there has been a troubling increase in the number of accidents associated with this group. Similar to data for other aircraft, the majority of these accidents are human error related. This investigation used the Human Factors Analysis and Classification System to categorize human error in HEMS operations. Like other aviation operations, skill-based errors comprised the majority of the unsafe acts, followed by decision errors, violations and perceptual errors. Also troubling was the number of fatalities associated with weather and night-related accidents, as well as controlled flight into terrain.

On January 11, 1998, near Sandy, Utah, an air ambulance was attempting to evacuate an injured skier when it impacted a ridge shortly after take off killing all on board. Witnesses reported blizzard conditions with wind gusts up to 35 knots, and significantly reduced visibility. Causes cited for the crash are an all too familiar litany of human error, including flight into known adverse weather, failure to maintain clearance, darkness, heavy snow, high winds, and perceived pressure to fly.

A 1966 report by the National Research Council of the National Academy of Sciences identified accidents as the leading cause of death for persons between the ages of 1 and 37, while listing it as the fourth leading cause of death for all ages. Based upon battlefield statistics which revealed a direct correlation between survival of battlefield wounds and prompt evacuation and treatment, the council recommended the use of helicopters for the transport of critically ill or injured patients to trauma centers that were equipped to handle these cases. This effort was further supported by the concept of the "The Golden Hour" which refers to the reduction in morbidity and mortality that results from immediate treatment of trauma victims (Cowley, 1976).

The first privately funded hospital-based helicopter program was established at St. Anthony's Hospital in Denver, CO in 1972 (Thomas, 1988). Since that time, helicopter emergency medical systems (HEMS) operators have undergone tremendous growth. In fact in 2001, according to the Association of Air Medical Services there were more than 300,000 patients transported.

Unfortunately, this growth has not come without some problems. A spate of accidents during a period of rapid growth from the early to mid 1980's raised some initial red flags. From 1980 to 1987 there were 54 accidents or an average of 7.7 accidents per year. This rate improved from 1988 to 1997 revealing an average accident rate of 4.9 accidents per year. Similar to other reports, (Blumen, 2002) we found that since 1998 there has been a steady and alarming increase in the accident rate of HEMS (Figure 1). Like other areas of aviation, the primary cause, cited in over 70% of the accidents, was human error. In fact, Blumen goes on to state that the most common factors included weather and dark night conditions.

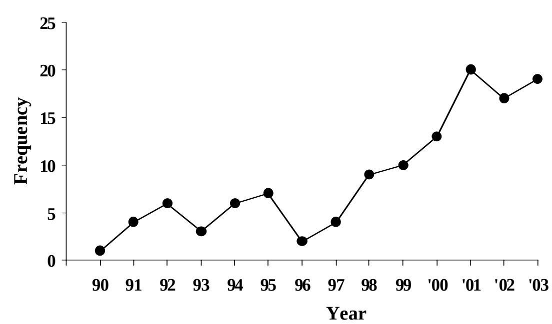

Figure 1: HEMS accidents by year

While discussions of accident rates, human error percentages, and environmental conditions may shed some light on the situation, they do not, in and of themselves provide the clarity necessary, to fully address the rise in accident rates. For that reason, an analysis of all HEMS accidents from 1990 to 2003 involving human error was conducted using the Human Factors Analysis and Classification System (HFACS).

HFACS

The entire HFACS framework includes a total of 19 causal categories within Reason's (1990) four levels of human failure. While in many ways, all of the causal categories are equally important; particularly germane to any examination of HEMS accident data are the unsafe acts of aircrew. For that reason, we have elected to restrict this analysis to only those causal categories associated with the unsafe acts of HEMS aircrew. A complete description of the HFACS causal categories is therefore beyond the scope of this report and can be found elsewhere (Wiegmann & Shappell, 2003).

Unsafe Acts of Operators

In general, the unsafe acts of operators (in the case of aviation, the aircrew) can be loosely classified as either errors or violations (Reason, 1990). Errors represent the mental or physical activities of individuals that fail to achieve their intended outcome. Not surprisingly, given the fact that human beings by their very nature make errors, these unsafe acts dominate most accident databases. Violations, on the other hand, are much less common and refer to the willful disregard for the rules and regulations that govern the safety of flight.

Within HFACS, the category of errors was expanded to include three basic error types (skill-based, decision, and perceptual errors). In general, decision errors represent conscious decisions/choices made by an individual that are carried out as intended, but prove inadequate for the situation at hand. In contrast, skill-based behavior within the context of aviation is best described as "stick-and-rudder" or other basic flight skills that occur without significant conscious thought. As a result, these skill-based actions are particularly vulnerable to failures of attention and/or memory as well as simple technique failures. Finally, perceptual errors occur when sensory input is degraded or "unusual," as is often the case when flying at night, in the weather, or in other visually impoverished conditions.

As with errors, there are many ways to distinguish between types of violations. However, two distinct forms are commonly referred to, based upon their etiology. The first, routine violations, tend to be habitual by nature and are often tolerated by the governing authority. The second type, exceptional violations, appear as isolated departures from authority not necessarily characteristic of an individual's behavior nor condoned by management.

METHOD

The National Aviation Safety Data Analysis Center (NASDAC) and NTSB were utilized to identify human-error-related HEMS accidents, specifically medical flights operating under 14 Part 91 (ferrying or repositioning flights) and 14 Part 135 (patient transport). This resulted in 121 accidents, as reported by the National Transportation Safety Board (NTSB) from 1990 to 2003. For the purpose of this report, we decided to limit the investigation to only those accidents (N=74) occurring in what we have termed the "rescue triangle" (see Figure 2). In addition, training accidents, fixed wing, and maintenance repositioning flights were also eliminated.

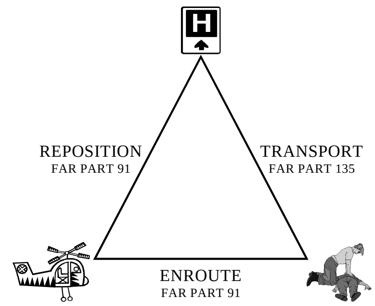

Figure 2: EMS Rescue Triangle

Subject Matter Experts

Six GA pilots were recruited from the Oklahoma City area as subject matter experts and received roughly 16 hours of training on the HFACS framework. All six were certified flight instructors with a minimum of 1,000 flight hours in GA aircraft (mean = 3,530 flight hours) as of June 1999. After training, the six GA pilot-raters were randomly assigned accidents so that two separate pilot-raters analyzed each accident independently. Using narrative and tabular data obtained from both the NTSB and the FAA NASDAC, the pilot-raters were instructed to classify each human causal factor using the HFACS framework. Note, however, that only those causal factors identified by the NTSB were classified. That is, the pilot-raters were instructed not to introduce additional casual factors that were not identified by the original investigation. To do so would be presumptuous and only infuse additional opinion, conjecture, and guesswork into the analysis process.

After our pilot-raters made their initial classifications of the human causal factors (i.e., skill-based error, decision-error, etc.), the two independent ratings were compared. Where disagreements existed, the corresponding pilot-raters were called into the laboratory to reconcile their differences and the consensus classification was included in the database for further analysis. Overall, pilot-raters agreed on the classification of causal factors within the HFACS framework more than 85% of the time, an excellent level of agreement considering that this was, in effect, a decision-making task.

RESULTS

As Figure 3 illustrates, human error accounts for the lions' share of the accidents in the HEMS population, as it does in all categories of aviation. Figure 3 illustrates the overall number of HEMS accidents, compared to those human error related accidents occurring in the rescue triangle only.

If one examines the characteristics of the curve, there is a steady increase in the number of accidents beginning in 1998, which is maintained through 2003.

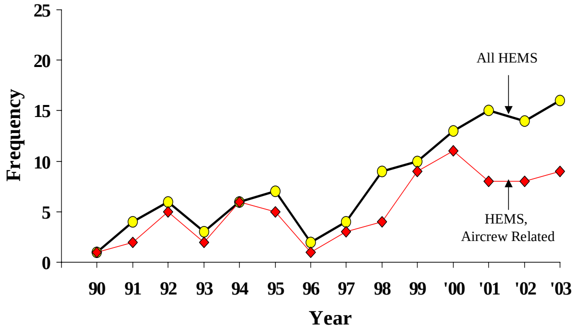

Figure 3: Human Error Associated HEMS Accidents

Unsafe Acts of the Operators

After applying HFACS codes to these data, the types of human error involved displays a familiar pattern (Figure 4), characterized by more skill-based errors (59.5%), followed by decision errors (33.8%), then perceptual errors (18.9%), and violations (14.9%). However, this in and of itself does not provide the resolution necessary to adequately assess what these unsafe acts means for aircrew operations.

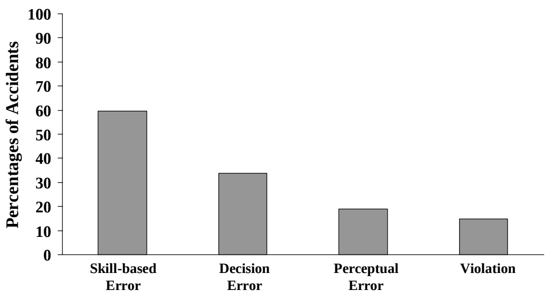

Figure 4: Unsafe Acts of the Aircrew

Fine-Grained Analysis

In order to better understand the types of errors made by HEMS aircrews, a fine-grained analysis was conducted to identify the specific types of unsafe acts that were associated with the HEMS accidents. The top three errors for each unsafe act are reported here. For skill-based errors, the most common errors were, failure to maintain clearance (28.6%), aircraft control, visual lookout, and altitude/clearance (8.2%). The top decision errors were in-flight planning/decision making and unintentional VFR flight into IMC (both 17.9%), followed by remedial action (10.7%). Perceptual errors consisted of aircraft control (25%), followed by distance/altitude and altitude/clearance (both 12.5%). Finally, the top violations were all weather related, including procedures and directives not followed (30.8%), VFR flight into IMC and flight into known adverse weather (15.4%).

As these data indicate, for skill-based errors, clearance from objects and terrain make up the bulk of the errors. On the other hand, decision errors, perceptual errors, and violations overwhelmingly were made up of errors that occurred in degraded conditions, either weather or night operations.

Relationship of Unsafe Acts to Fatalities. When the relationship of unsafe acts to fatalities was examined, the data revealed that those accidents associated with violations claimed a higher percentage of lives, compared to the other categories of unsafe acts. Of those accidents involving a skill-based error, 31.8% resulted in a fatality, compared with 20% for decision errors, and 42.9% for perceptual errors. However, when a violation was involved, 63.6% of these accidents had at least one fatality (Figure 5). This is consistent not only with other flight deck operations, but with maintenance violations as well.

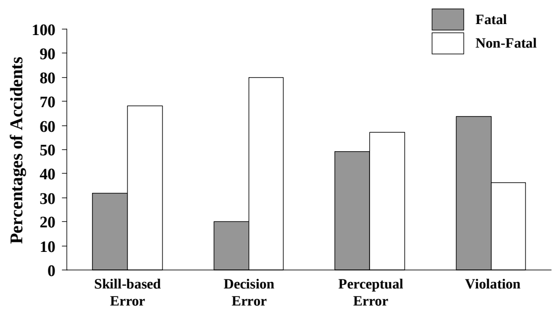

Figure 5: Fatalities Related to Unsafe Acts

Accidents by Position. When the data were analyzed by position alone (enroute, transport, or reposition), the largest number of accidents was found in the enroute phase, followed by reposition, then transport. This was expected since one may assume more pressure to arrive at the pickup site as quickly as possible (Figure 6).

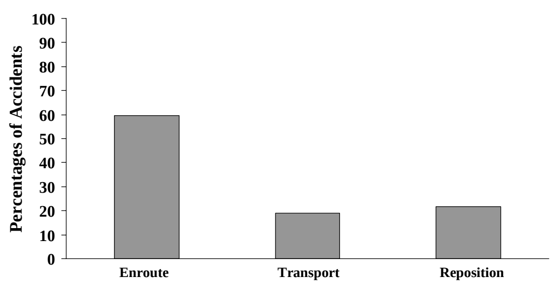

Figure 6: Percentage of Accidents by Position

Phase of Flight. Because of the unique nature of the HEMS flight operations, an analysis of phase of flight by position was conducted. During the enroute portion of the rescue triangle, the greatest number of accidents occurred during cruise and landing (both 20.5%), followed by approach and maneuvering (both 17.9%). Takeoff accounted for 12.8% followed by hover, taxi, and emergency descent (5.1%, 2.6%, and 2.6% respectively). For the transport phase of the triangle, the bulk of the accidents occurred during the takeoff phase of flight with 58.3% of the accidents occurring while leaving the scene. The remaining accidents were evenly distributed during climb, descent, approach, go-around, and maneuvering, all with 8.3% of the accidents. Finally, during reposition, the majority of the accidents occurred during cruise flight (46.2%), followed by takeoff (15.4%). The remaining accidents were divided by standing, descent, approach, landing, and emergency landing after takeoff, with 7.7% of the accidents occurring in each of these phases.

Lighting Conditions. In order to determine the effects of time of day on HEMS operations, the data was divided into day vs. night operations. Furthermore, rather than simply compare accident rates associated with time of day; fatalities associated with time of day were also analyzed (Figure 7).

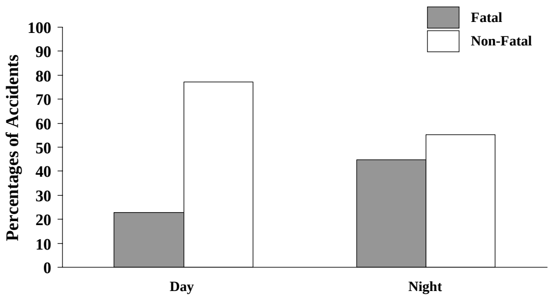

Figure 7: Fatalities by time of day

While the actual percentages of accidents associated with time of day were relatively evenly split between day and night, 47.9% and 52.1% respectively, the breakdown in fatalities was not. As can be noted in Figure 7, 22.9% of daytime accidents were associated with fatalities compared with 44.7% fatalities when the accident occurred at night.

Weather Conditions. The vast majority of HEMS accidents occurred in VMC weather (74.3%) vs. IMC (25.7%) However, similar to the analysis of lighting conditions, there were more likely to be fatalities associated with IMC weather (Figure 8). When examining the relationship between fatalities and weather conditions, IMC operations took a greater toll with 73.7% resulting in fatalities, compared with only 20.0% of VMC related accidents resulting in fatalities. To better illustrate this point, the odds of dying in an accident in IMC weather are 11 times greater when compared to VMC conditions.

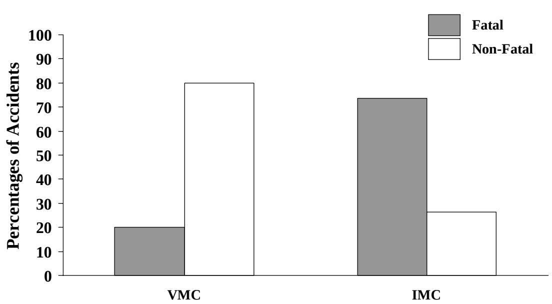

Figure 8: Fatalities related to weather conditions

Controlled Flight into Terrain/Obstacle. Because there were 25-controlled flights into terrain (CFIT) in this population, a closer look was called for. For this analysis, CFITs were broken down into two categories, controlled flight into terrain (CFIT/T) and controlled flight into obstacle (CFIT/OBS). In order to gauge the effects of degraded conditions on the occurrence of CFITs, an impoverished variable was created by combining both night/dusk conditions or poor weather creating an impoverished variable. The results are displayed in Figure 9. As can be seen by the graph, the likelihood of CFIT/T greatly increases in impoverished conditions.

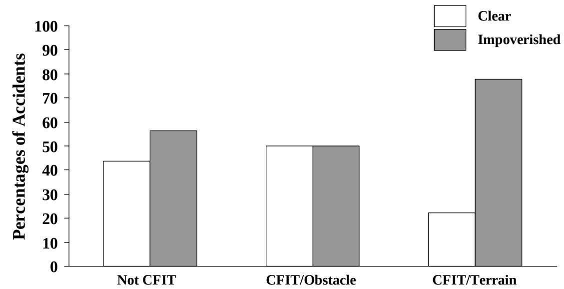

Figure 9: CFIT to Environmental Conditions

A similar analysis was carried out to determine the relationship of the different types of CFITs to fatalities. As Figure 10 illustrates, there was an increased likelihood of a fatality in a CFIT/T compared to CFIT/OBS (88.9% vs. 31.3%).

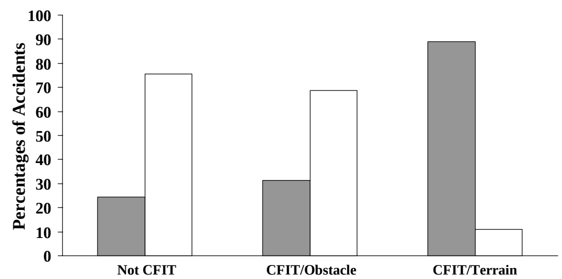

Figure 10: Relationship of CFIT to Fatal (Solid bars) vs. Non-Fatal (Clear bars) Accidents.

DISCUSSION

Human error involved in HEMS accidents was classified using HFACS, allowing for a higher level of description than is typically associated with standard reporting. For the purpose of this investigation, only those human error-related accidents occurring within what has been termed the rescue triangle have been analyzed. This was done in an attempt to capture what is a true HEMS operation. While it is understood that these do not make up all of the theaters within which HEMS flights operate (training, maintenance ferry flights, etc…) it was believed that the unique pressures involved in these operations are reflected within these limits.

In reviewing the data for unsafe acts, we see patterns similar to other aviation platforms. Skill-based errors were the most common type of human error in HEMS accidents, followed by decision errors, then perceptual errors and violations. Notably, however is the greater number of fatalities associated with violations when compared to the other unsafe acts. Those accidents, which involved violations, were 3 times more likely to be associated with a fatality. Similar data are reported in other studies using the HFACS (Shappell and Wiegmann, 2003).

Whereas the unsafe acts resemble other aviation platforms, the fine-grained analyses revealed some important differences. For instance, the observation that the top three violations were weather related speaks volumes for what are VFR operations, and what has plagued HEMS operations over the years. This is consistent with other reports, which cite weather as a problem in HEMS operations (Frazer, 1999). While it may be easy to blame the pilot who ultimately has the go/no go decision, one must also keep in mind that many have to rely on local weather forecasts, which may lack the detail necessary for pilots to make informed decisions in questionable weather. Thus, pilots may takeoff expecting the back door to be open for a return, only to find it quickly closed. Furthermore, pressure to fly, either self-induced because of the nature of the operation or induced by pressure to generate revenue, must be factored into the decision-making process.

When the position of the flight within the rescue triangle was considered, the greatest number of accidents was shown to occur in the enroute phase. This is not surprising, since this is the time when one may assume (although it is only an assumption) that the greatest pressure to "get there" may be present. While transport and reposition were not significantly different, it was somewhat surprising that slightly more accidents were occurring during the reposition phase. Frazer (1999), states that "get home itis" may be involved in these types of accidents. However, it may also be that during this phase, the aircrew may experience some complacency since the emergency is passed, thus, they may be somewhat less vigilant in the cockpit.

Phase of flight revealed that during the enroute phase of operation, cruise and landing were most problematic. Landing is best explained by the fact during this phase, the aircraft are landing at unimproved sites, often during less than ideal conditions. Cruise is somewhat more difficult to explain except that here is where pressure to arrive at the scene in the least amount of time may be at work. For transport, takeoff was by far associated with the most accidents. Again, the fact that aircraft are taking off from unimproved sites, contending with wires, fences, trees, etc… may best explain these data. Finally, during reposition, cruise accounted for almost 50% of the accidents. It is here that complacency and "get home itis" may factor into these accidents.

Consistent with the findings from Frazer in 1999, there was no difference in the number of accidents occurring during the day when compared to night operations. However, we took the analysis one step further, and found that those accidents occurring at night were almost twice as likely to be associated with a fatality. This should certainly be cause for scrutiny of the nighttime VFR operation that HEMS flies under.

The relationship for VFR vs. IMC conditions is even more lopsided. While the vast majority of accidents occurred in VMC conditions, the fatality rate associated with IMC related accidents was almost three times greater. Thus, flying in degraded conditions, whether due to darkness or poor weather, the chances of an accident do not necessarily go up, however, should an accident occur, the probability of a fatality greatly increases. Based upon these findings, accidents in poor weather, as well as darkness are costly indeed.

Nowhere is this more evident than in CFIT accidents. In comparing CFIT/OBS to CFIT/T, there were 16 CFIT/OBS with 8 occurring in clear conditions, and 8 occurring in impoverished. For CFIT/T, there were 9 accidents with 2 occurring in clear conditions and 7 occurring in impoverished conditions. Thus, for CFIT/T, there was over three times the number of accidents in degraded conditions. To make matters worse, of those 9 CFIT/T accidents, 8 included a fatality, compared with 5 for CFIT/OBS. This computes to a 2.5 times greater risk of a fatality if an aircrew is involved in a CFIT/T vs. CFIT/OBS.

So where does this leave the HEMS? While it is easy to sit back and in retrospect "arm chair quarterback" an industry that has become a mainstay of emergency medicine, the answers will not be as simple as they seem. Number one on the list to be addressed are operations in degraded conditions. The obvious recommendation here are IMC equipped aircraft and pilots who are truly instrument certified. While this may seem counterintuitive for an industry that operates under VFR rules, the number and severity of accidents that occur in weather and in night conditions coupled with the number of weather-related violations indicates that the time has come to consider IFR currency and similarly equipped aircraft.

Another solution that has been batted about are dual crew and dual engine aircraft. However, this presents problems for smaller operations, due to the increased expense of these aircraft and higher costs associated with additional crewmembers. Night vision goggles (NVGs) have also been suggested due to the number of accidents that occur at night. However, this is not supported by the data. Specifically, there were no more accidents at night compared to daytime operations. And while the severity of accidents occurring at night are greater in terms of fatalities, most of the nighttime accidents occurred in IMC, where NVGs would have been of no use Furthermore, NVGs do not increase visibility of wires and fence lines which pose problems at landing and take-off sites.

Finally, training for on-scene responders should be standard operating procedure. Law enforcement and ground crews should be educated as to where helicopters can safely land and take off from. They should be aware of what HEMS crews can and cannot see from the air, how much room they need to land and maneuver, how soft the ground can be before there is a problem, etc… This may help to decrease many of the landing and takeoff accidents noted in the enroute and transport phase of the operation.

It should be understood that any operation has a certain amount of risk associated with it, and HEMS operations are no different. But there are two ways to go about reducing this risk. One is to make the operation safer, in other words, to reduce the probability of an accident. The second is to reduce the exposure to the environment within which the accidents take place. While most of the efforts are focused on the first solution (with little success), the second solution is often ignored. However, it may be time to ask, how many of the operations flown are true emergencies? Should HEMS operations be used to transfer stable patients, and if so, under what conditions should these be considered? How are go/no go decisions made, and by who? At what point should a transport be turned down?

Taken altogether, these recommendations may help to alleviate some of the problems facing HEMS today. For as the data pointed out, we are not facing one problem, but numerous issues, all of which must be addressed. In particular, we need to go beyond the aircrew and study the system in which they operate. This should include a two pronged approach: 1) We must understand the culture within which the aircrews operate. This should include not only the supervisory and organizational issues, but aircraft environment such as protective clothing, helmets, instrument tie downs, etc… and 2) a detailed analysis of current regulations in order to understand how regulatory practices interact with HEMS operations. Only by doing this can we hope to fix the system.

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