EMS Helicopter Crashes: What Influences Fatal Outcome?

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Study objective: In recent years, air transport of patients has been associated with disproportionate increases in crashes and deaths. We identify factors related to fatal outcome in air medical helicopter crashes and suggest preventive measures.

Methods: This was a retrospective study using National Transportation Safety Board records for helicopter emergency medical services (EMS) crashes between January 1, 1983, and April 30, 2005. The main outcome measure was the percentage of air medical crashes resulting in 1 or more deaths.

Results: There were 182 helicopter EMS crashes during the 22.3-year study period; 39% were fatal. One hundred eighty-four occupants died: 45% of the 44 patients and 32% of the 513 crewmembers. Fifty-six percent of crashes in darkness were fatal compared with 24% of crashes not in darkness. Seventy-seven percent of crashes in instrument meteorological conditions were fatal compared with 31% in visual conditions. Thirty-nine percent of all deaths occurred in crashes with postcrash fires; 76% of crashes with postcrash fire were fatal compared with 29% of other crashes. Multivariate logistic regression revealed that controlling for other factors, the odds of fatal outcome was increased by postcrash fire (odds ratio [OR] 16.1; 95% confidence interval [CI] 5.0 to 51.5], bad weather (OR 8.0; 95% CI 2.4 to 26.0), and darkness (OR 3.2; 95% CI 1.3 to 7.9).

Conclusion: Fatalities after helicopter EMS crashes are associated especially with postcrash fire and with crashes that occur in darkness or bad weather and can be addressed with improved crashworthiness and measures to reduce flights in hazardous conditions. Further studies will be necessary to determine which changes will decrease the fatal crash rate and which are cost effective. [Ann Emerg Med. 2006;47:351-356.]

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INTRODUCTION

Background

Air transport of patients between medical facilities and directly from crash scenes to hospitals has increased dramatically in recent years, with disproportionate increases in crashes and deaths. After a 15-year decline, crash rates of helicopter emergency medical services (EMS) flights increased from 1.7 per 100,000 flight hours in 1996 to 1997 to 4.8 in 2003 to 2004.[1]

Importance

Although crash involvement rates have generally been lower for helicopter EMS than for general (private) aviation, the rate of fatal crashes in helicopter EMS operations from 1997 to 2001 was higher than the rate for all other categories of aviation, including general aviation: 1.7 per 100,000 hours for helicopter EMS compared with 1.3 for general aviation.[2] This discrepancy reflects a high proportion of helicopter EMS crashes with fatal outcome.

In addition to concern for survival of patients is the occupational risk to pilots, paramedics, and flight nurses. Based on estimates of the numbers of crewmembers and crew deaths during 1995 to 2001,[2] the death rate of helicopter EMS crewmembers was 75 per 100,000 person-years, 16 times the occupational injury death rate of 4.6 for all US workers during this period.[3] Wright[1] reported an average rate during 2000 to 2004 of 1.8 fatal helicopter EMS crashes per 100,000 flight hours. At this rate, a helicopter EMS pilot or crewmember

Editor's Capsule Summary

What we already know about this topic
Helicopters can speed patients to the hospital but do so with the added risks of air travel.

What questions this study addressed
What is the frequency of crashes of medical helicopters in the U.S. and what factors are associated with fatal crashes?

What this study adds to our knowledge
There were one or more fatalities in 39% of the 182 crashes in the past 22 years killing 20 patients and 164 staff. Fatal crashes were strongly associated with postcrash fire and with flying at night or in bad weather. The death rate among helicopter EMS crew members is much higher than the occupational death rate for all U.S. workers.

How this might change clinical practice
Helicopter EMS programs should recognize those conditions associated with fatal crashes and use helicopters only when the benefit clearly exceeds the risk. Judicious use of medical helicopters in bad weather and at night might reduce the rate of fatal crashes.

flying 20 hours per week during a 20-year career would have a 37% chance of being in a fatal crash ($20\times52\times20\times1.8/100{,}000=37\%$).

Goals of This Investigation

Attention to the problem has emphasized factors contributing to the occurrence of helicopter EMS crashes, such as weather [2,4] and the competition created by proliferation of air medical services.[2,5] Equally important but largely ignored are issues related to survival when crashes occur. The risk to patients and crew prompted a study to identify factors related to fatality in helicopter EMS crashes.

MATERIALS AND METHODS

Study Design

We performed a retrospective study of all fatal and nonfatal EMS helicopter crashes in the United States in a defined period. The institutional review board at the Johns Hopkins School of Public Health exempted the study from formal review.

Selection of Participants

The National Transportation Safety Board (NTSB) investigates and records data for all civil aviation crashes. A crash ("accident" in NTSB terminology) is defined as an occurrence associated with operation of an aircraft resulting in death or serious injury or substantial aircraft damage. The NTSB database of crashes since 1983[6] was downloaded, and records for all 4,329 helicopter crashes between January 1, 1983, and April 30, 2005, were selected.

Helicopter EMS crashes since 2000 were identified by a "yes" in the "Air Medical" field, which was added in 2000. Earlier helicopter EMS crashes had been identified previously by one of the authors (RSD) by reading the narratives for all helicopter crashes. Cases identified by these 2 methods were supplemented with cases found through searches for key words: "EMS," "ambulance," "paramedic," "medevac," "mercy," "nurse," or "patient."

Data Collection and Processing

Descriptions of the crashes were read and details coded and merged with coded data from NTSB data files. Data selected for analysis included the month, mission of the flight, pilot flight time, light conditions, weather, number of engines, and postcrash fire. We examined the influence of light conditions in addition to time of day because the hours of darkness vary by several hours, depending on time of year and geographic location. Crashes during dusk were combined with daylight crashes in the analysis; no crashes were coded as occurring during dawn.

Primary Data Analysis

Factors associated with fatal outcome were identified by comparing fatal crashes to nonfatal crashes. The main outcome measure was the percentage of crashes resulting in 1 or more deaths. Variables considered to be possibly related to fatal outcome were selected for bivariate analysis. Those variables for which the confidence interval (CI) of the odds ratio (OR) did not include 1 were then included in a multivariate logistic regression analysis to determine the odds of a factor being related to fatal outcome; 95% CIs were used. Data analysis was performed with SAS version 8.0 (SAS Institute, Inc., Cary, NC).

RESULTS

There were 182 crashes of helicopter EMS flights in the United States during the 22.3-year study period, an average of 8.1 per year. Fifty-three helicopter EMS crashes were identified by the "air medical" field, 110 by the list of helicopter EMS crashes before 2000, and 20 were found only by means of reading records identified through word searches.

From 1998 through April 2005, there were 88 helicopter EMS crashes, an average of 12 per year, compared with 8.6 per year during 1983 to 1989 and 4.3 during 1990 to 1997. Figure 1 illustrates the yearly variation.

Seventy-one crashes (39%) were fatal. There was at least 1 survivor in 26 (37%) of the fatal crashes. One hundred eighty-four occupants died, a rate of 1,011 deaths per 1,000 crashes. Twenty of 44 patients (45%) and 164 of 513 crewmembers (32%) died.

Crashes were distributed fairly evenly through the year but were somewhat more likely to be fatal during December to February (Table).

The mission was unknown for 22 (12%) flights. Of the remaining flights, 32% were going to pick up patients, 28% had patients on board, and 29% were returning to base or otherwise positioning; 12% were not directly related to patient transport but were for refueling, training, demonstration, or ferrying.

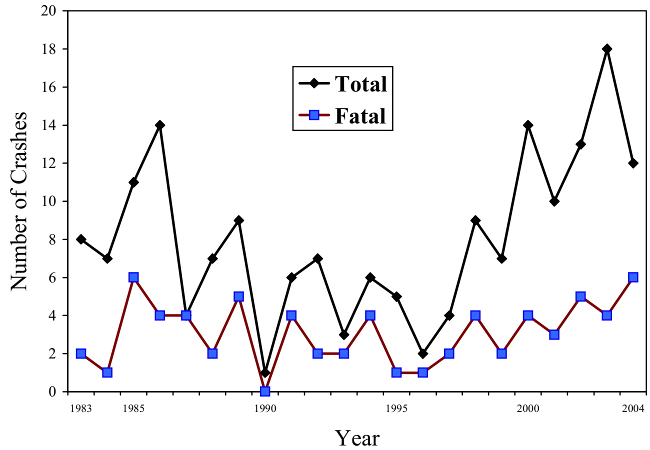

Figure 1. Number of crashes of EMS helicopters by year, United States 1983-2004.

Pilots' total flight time averaged 6,230 hours for those in nonfatal crashes and 5,968 in fatal crashes. Four percent of pilots had fewer than 2,000 hours total time, and 23% had fewer than 100 hours in the type of aircraft flown. Flight time was not related to crash outcome.

Crashes in darkness comprised 48% of all crashes and 68% of fatal crashes. Crashes in the dark were more likely to be fatal than daytime crashes, 56% versus 24% (Table). The majority of crashes between 7 PM and midnight and between 5 and 6:59 AM were fatal (Figure 2).

In 30 crashes (17%), the NTSB reported the basic weather as instrument meteorological conditions; 77% of instrument meteorological conditions crashes were fatal compared with 31% of crashes in visual meteorological conditions (Table).

Thirty-three crashes (19%) involved postcrash fire; 76% of these 33 crashes were fatal. In contrast, only 29% of crashes without fire were fatal (Table). Postcrash fires were associated with 72 deaths; thus, 39% of all deaths occurred in crashes with postcrash fires. In 6 crashes with postcrash fire, there were survivors, as well as fatalities.

Multivariate logistic regression analysis examined the odds of fatality in relation to mission, season, number of occupants, darkness, weather, and postcrash fire, controlling for each of the other variables. The odds of a crash being fatal were increased by postcrash fire (OR 16.1; 95% CI 5.0 to 51.5), bad weather (OR 8.0; 95% CI 2.4 to 26.0), and darkness (OR 3.2; 95% CI 1.3 to 7.9).

LIMITATIONS

Before 2000, there was no specific identifier for air medical cases in the NTSB database. Even after 2000, about one fifth of the helicopter EMS crashes were not identified as such in the NTSB file. It is possible that a few minor crashes during the study period were missed because the text contained none of our search terms. Thus, a small undercount of cases may have occurred, which would have resulted in a corresponding overestimate of the percentage of crashes resulting in death. If any deaths were unrecognized because they occurred 30 days or longer after a crash, this would have caused a small underestimate of the percentage of crashes resulting in death.

As with any retrospective analysis, this study is limited by the scope and quality of archived data. For instance, we were unable to examine the special safety hazards of landing at undesignated landing sites, because of the lack of information in the NTSB data system. An important limitation is that data were not available to indicate whether the fatal crashes with postcrash fire might have been survivable in the absence of fire. Although it would be anticipated that crashes with fire usually involved higher crash forces, 6 postcrash fires had survivors, as well as fatalities, indicating that the crash forces per se were not necessarily fatal.

Table. Percentage of EMS helicopter crashes resulting in fatality: United States, 1983 to April 2005.

Characteristic	Total (n=182)	Fatal, No.	Fatal, %	Ratio of % Fatal (95% CI)
Month of crash				
March–May	43	16	37.2	1
June–August	49	17	34.7	0.9 (0.7–1.1)
September–November	42	13	31.0	0.8 (0.6–1.0)
December–February	48	25	52.1	1.4 (1.1–2.2)
Mission*				
Positioning	46	18	39.1	1
Going for patient	51	17	33.3	0.8 (0.6–1.0)
Patient transport	44	23	52.3	1.3 (1.0–1.6)
Other	19	6	31.6	0.8 (0.6–1.0)
Number of occupants				
1–3	129	45	34.8	1
4–6	53	26	49.1	1.4 (1.2–1.6)
Light condition*				
Dark	86	48	55.8	2.3 (2.0–2.6)
Daylight/dusk	95	23	24.2	1
Instrument conditions*				
Yes	30	23	76.7	2.5 (2.1–2.9)
No	147	45	30.6	1
Number of engines*				
1	82	34	41.5	1
2	98	36	36.7	0.9 (0.8–1.0)
Postcrash fire*				
Yes	33	25	75.8	2.6 (2.2–3.0)
No	141	41	29.1	1

*Some missing observations.

DISCUSSION

The contribution of darkness and bad weather to the likelihood of helicopter EMS crashes is well known.[2] This study of the outcome of crashes reveals that when a helicopter EMS crash occurs, darkness more than triples the risk of fatalities, and bad weather increases the risk 8-fold. Both threats to survival underscore the importance of adopting and following standard algorithms to identify the medical necessity for air transport.

Our findings that darkness, weather, and fire are major determinants of survival underscore the need to improve aircraft

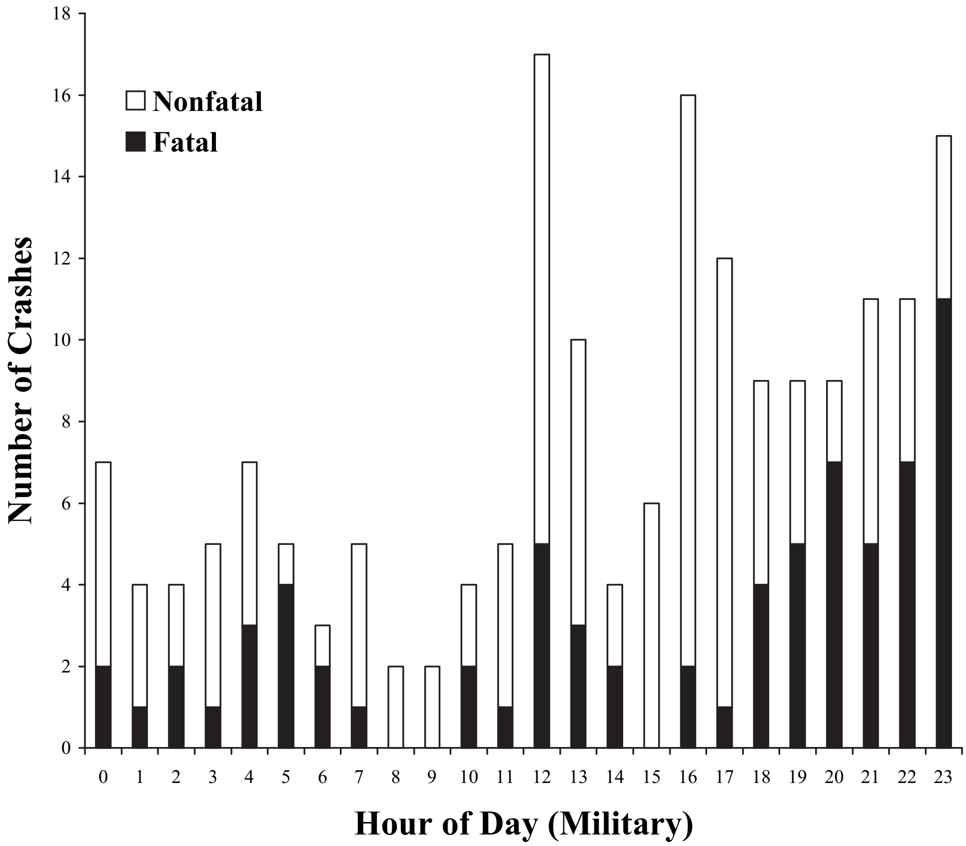

Figure 2. Number of crashes of EMS helicopter crashes by hour of the day, United States 1983 to April 2005.

equipment and crashworthiness. The costs of such improvements can often be justified by potential benefits.[7] It is estimated that there are 650 helicopters in the United States dedicated to air medical service,[1] and the present series revealed an average of 12 helicopter EMS crashes per year in recent years. Thus, 1 medical helicopter in 4 is likely to crash during 15 years of service (12×15/650=28%), which suggests that investments in prevention have the potential to be highly cost effective.

The 3-fold increase in the odds of a crash being fatal probably reflects greater crash forces when a pilot cannot see well enough to anticipate a crash and guide the helicopter to a less damaging collision, as well as difficulties in nighttime search and rescue. To reduce the likelihood of crashes and deaths in night flights, many have argued for night vision goggles and helicopters equipped for night vision flight.[2,7–10] Most EMS helicopters have a single pilot, who must see well enough to identify and avoid potential threats while managing the flight controls and communications. Because of the cost of night vision goggles and related helicopter modifications, few companies have invested in them; goggles and aircraft modifications plus the cost for initial training for the pilot and the medical crew total $130,000 to $150,000.[11] The effectiveness of night vision goggles in reducing crashes has not been evaluated, but there have been no helicopter EMS crashes involving controlled flight into terrain where night vision goggles were in use.[10] The extent to which night vision goggles might increase hazardous, low visibility flights, with potential negative consequences, is unknown.

Reductions in night flights may be appropriate when ground transport is a feasible alternative, as is the case in much of Europe, where nighttime helicopter EMS flights are rare. US programs might consider policies to reduce nighttime patient transfers by air that could be postponed until daylight or, especially in more urban locations, replaced by ground transport when a patient's condition permits. Research is needed to improve the ability of first responders to identify patients who are unlikely to benefit from air transportation.[12–15] These considerations address the underlying problem of exposure to flight risks under hazardous circumstances. The rationale for reducing exposure is supported by reviews of air medical transports showing that air transport in the majority of cases was not warranted.[16,17]

An increased risk of fatal outcome in weather-related crashes was previously reported by Li and Baker,[18] who found a 4-fold risk of fatality in crashes of commuter flights that encountered reduced visibility. Thirty helicopter EMS flights—one sixth of the total—crashed in instrument meteorological conditions, with an OR of 8.0 for fatal outcome. All but one were single-pilot operations. In this scenario, it is not uncommon for pilots to lose control of the helicopter due to spatial disorientation.

Although autopilots could reduce the risk of helicopter EMS crashes at night or due to unanticipated poor weather and spatial disorientation, visual flight rules programs are not required to have an autopilot, even for single-pilot operations.

As with darkness, bad weather increases the potential benefit of ground transport. Helicopter EMS programs could benefit from decision protocols such as that used by the Coast Guard,[19] in which high-risk flights require command endorsement, a role that could be met by a helicopter EMS safety officer. The Federal Aviation Administration has recently suggested factors for safe decisionmaking.[20] One list assigns a weight to pilot experience, unfamiliar location, weather, and nighttime, with additional weight given to flights between 2 and 5 AM.

Most safety recommendations for air medical flights have focused on crash prevention measures. Survival after crashes is equally important but has received little emphasis. In the present study, half of all fatal crashes had at least 1 survivor, suggesting that some deaths in those crashes might have been prevented through greater attention to helicopter crashworthiness including better restraints, energy-absorbing seats and landing gear, crash-resistant fuel systems, and "delethalization" of interiors. Dodd [21] found that crewmembers in the main cabin of EMS helicopters were at more than 4 times the risk of injury in survivable crashes compared with crewmembers in the cabins of non-EMS helicopters, in part because of cabin modifications for patient care and transport. Energy-attenuating seats, unavailable for the medical crew in many helicopters because they are required only for newly certificated helicopters, could reduce the vertical forces to survivable levels in many crashes.[22] Recent crew deaths have occurred because some EMS helicopters lack shoulder harnesses at nonpilot positions,[8] indicating the need to require retrofitting helicopters that were designed without shoulder harnesses and are now being used for medical transport.

Postcrash fire increased the odds of fatal outcome 16-fold, more than any other factor. Nineteen percent of crashes and 39% of all deaths were associated with postcrash fire. Crash-resistant fuel systems, which include tanks and fittings that do not release fuel in a potentially survivable crash, might have prevented some of the postcrash fires. Crash-resistant fuel systems have virtually eliminated fire deaths in survivable crashes of US Army helicopters [22,23] but have not been incorporated in the great majority of civilian helicopters. Crashes of Bell 206 helicopters equipped with crash-resistant fuel systems have been associated with a reduced rate of postcrash fire.[24]

Thirty-nine percent of all helicopter EMS crashes result in 1 or more deaths. The risk of fatal outcome is greatly increased in crashes that occur at night or in bad weather or that result in postcrash fire. The high risk of death associated with air medical transport could be addressed through a variety of approaches. Further studies will be necessary to determine which changes will cost effectively decrease the fatal crash rate.[12]

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Author contributions: SPB, RSD, and MWL conceived the study. SPB and GHL obtained research funding. SPB and MWL read and coded the case reports. SPG and JGG supervised data collection, and JGG performed data analyses. SPB, RSD, DFS, and MWL interpreted the results of analyses. GHL was the statistical consultant. SPB drafted the manuscript, and all authors contributed substantially to its revision. SPB takes responsibility for the paper as a whole. Reprints not available from the authors.

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REFERENCES

1. Wright RM Jr. Air medical service, an industry under scrutiny. *Rotor.* Winter 2004-2005:6-8.
2. Blumen IJ, and UCAN Safety Committee. *A Safety Review and Risk Assessment in Air Medical Transport: Supplement to the Air Medical Physician Handbook*. Salt Lake City, UT: Air Medical Physicians Association; 2002.
3. National Safety Council. *Injury Facts: 2004 Edition*. Chicago, IL: National Safety Council; 2004.
4. Springer B. The IFR bullet: can it kill our accident rate? *Air Med J*. 2005;24:29-31.
5. Bachman J. State grounds WakeMed's request for air ambulances. WRAL January 25, 2005. Available at: http://www.flightweb.com. Accessed December 19, 2005.
6. National Transportation Safety Board. Aviation data. Available at: ftp://www.ntsb.gov/avdata/Access95/.
7. Dodd RS. The cost-effectiveness of air medical helicopter crash survival enhancements: an evaluation of the costs, benefits and effectiveness of injury prevention interventions. *Air Med J*. 1994; 13:281-293.
8. Helicopter Air Ambulance Accident Task Force. *Helicopter Air Ambulance Accident Analysis and Recommendations: U.S. Department of Transportation, Federal Aviation Administration, Interim Report: December 21, 2004*. Washington DC: Helicopter Air Ambulance Accident Task Force; 2004.
9. Gamauf M. Double tragedy: helicopter EMS accidents. *Business Comm Aviation*. December, 2004;60-64.
10. Megna D. Conquering the night: night-vision goggles in the civil helicopter industry [Helicopter Monthly Online Magazine Web site]. Available at: http://www.helicoptermonthly.com/detail.cfm?CFID=2376270&CFTOKEN=40574478&ItemID=252&CategoryID=13. Accessed March 11, 2005.
11. Atwood M. Lessons learned in the night-vision goggle world: night vision goggle operations. Association of Air Medical Services Night-Vision Goggle Conference. Dallas, TX, July 25-26, 2005.

12. Fries GR, McCalla G, Levitt MA, et al. A prospective comparison of paramedic judgment and the trauma triage rule in the prehospital setting. *Ann Emerg Med*. 1994;24:885-889.
13. Henry MC, Hollander JE, Alicandro JM, et al. Incremental benefit of individual ACS trauma triage criteria. *Acad Emerg Med*. 1996; 3:992-1000.
14. Wuerz R, Taylor J, Smith JS. Accuracy of trauma triage in patients transported by helicopter. *Air Med J*. 1996;15:168-170.
15. Bond RJ, Kortbeek JB, Preshaw RM. Field trauma triage: combining mechanism of injury with the prehospital index for an improved trauma triage tool. *J Trauma*. 1997;43:283-287.
16. Bledsoe BE, Smith MG. Medical helicopter accidents in the United States: a 10-year review. *J Trauma*. 2004;56:1325-1329.
17. Bledsoe BE, Wesley AK, Eckstein M, et al. Helicopter scene transport of trauma patients with non-life-threatening injuries: a meta-analysis. *J Trauma*. In press.
18. Li G, Baker SP. Crashes of commuter aircraft and air taxis: what determines pilot survival? *J Occup Med.* 1993;35:1244-1249.
19. US Coast Guard. Operational risk management: commandant instruction 3500.3, 23 Nov 99, p 57-79. Available at: http://www.uscg.mil/hq/g-w/g-w/g-wk/wks/AviationHome.htm. Accessed December 20, 2005.
20. Federal Aviation Administration. Helicopter emergency medical services operator risk assessment programs. Available at: http://www.faa.gov/library/manuals/examiners_inspectors/8000/. Accessed December 20, 2005.
21. Dodd RS. Factors involved in emergency medical service helicopter occupant crash survival. *Trans Res Rec*. 1992;1332:1-10.
22. Shanahan DF. *Basic Principles of Helicopter Crashworthiness*. Fort Rucker, AL: United States Army Aeromedical Research Laboratory; 1993. USAARL Report No. 93-15.
23. Knapp SC, Allemond P, Karney DH. Helicopter crashworthy fuel systems and their effectiveness in preventing thermal injury. AGARD conference proceedings No. 225; May 1-5, 1978; Fort Rucker, AL. Neuilly Sur Seine, France: AGARD; 1978:61-1 to 61-7.
24. Hayden MS, Shanahan DF, Chen L-H, et al. Crash resistant fuel system effectiveness in civil helicopter crashes. *Aviat Space Environ Med*. 2005;76:782-785.