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A Review of Air Medical Safety: 2005-2011

Andrew Holcomb
Eastern Kentucky University

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By

ANDREW ALLEN HOLCOMB

Thesis Approved:

Dr. Scotty Dunlap, Chair, Advisory Committee

Dr. Sandy Hunter, Member, Advisory Committee

Paul English, Member, Advisory Committee

Dean, Graduate School

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By

ANDREW ALLEN HOLCOMB

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Eastern Kentucky University
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DEDICATION

This thesis is dedicated to all the EMS responders that have died while in the line of duty.

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I would like to thank the support of my family and friends. Further, I want to thank the faculty, especially my thesis committee, of Eastern Kentucky University who helped me immensely in writing this thesis. Finally, I extend great appreciation to all the EMS professionals that assisted me in research and support in terms of making air medical operations safer.

ABSTRACT

This study was designed to research current air medical risks and identify the extent of the risk from 2005 – 2011 by looking at NTSB data. Sixty-eight rotorcraft air medical incidents were discovered based on preset criteria, such as resulting injury or significant damage to aircraft, for severe air medical incidents. Six major concerns in air medical safety were researched in this study: day and nighttime incidents, takeoff/landing and in-flight incidents, Part 91 and Part 135 regulations, pilot hours, post-crash fire, and changing visual conditions. From information given in the NTSB reports based on incident investigation, this information was collected then analyzed for statistical significance.

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CHAPTER I

INTRODUCTION

In serious emergency incidents when seconds count, a medical helicopter that transports a patient to an advanced hospital can mean the difference between the life and death. Unfortunately, the death of the patient may not occur due to incident for which the medical helicopter was dispatched for but may in fact be due to the helicopter crashing while transporting the patient to the hospital. Air medical services are in the business to save the lives of critical patients, but unfortunately, flight crews and patients become victims when crashes and fatalities occur during these high-risk operations. Even more concerning is that rate of crashes are skyrocketing. According to Baker et al. (2006), the air medical helicopter crash rate per 100,000 flying hours was 1.7 from 1996 to 1997 and 4.8 from 2003 and 2004. Further, a rate of 1.8 per 100,000 flying hours was noted from 2000 to 2004. At a rate of 1.8, a crewmember would have a 37% chance of becoming a fatality flying 20 hours per week for 20 years (p. 351-352). The risk of injury and death from air medical crashes seems to outweigh the risk of a patient becoming a victim due to inadequate medical care. Unfortunately, Foo, Ahghari, and MacDonald (2010) state that "discontinuation of existing air medical transport, in one setting, resulted in a fourfold increase in mortality for patients transported from a rural hospital" (p. 463). In terms of trauma care, a common industry practice is to utilize the "golden hour" rule in which a patient has a better chance of survival from the time the incident occurs to arrival at the emergency room in less than one hour where surgery can occur. In a rural setting, it can be extremely challenging, if nearly impossible, to meet this principle even with air medical transportation. Typically, a rural hospital does not have the capability to meet the needs for advanced traumatic surgery, and a patient requires a higher-level of care at a A regional trauma center. With both aspects of the problem in mind, research into why air medical crashes occur is paramount to operational as well as public safety. Due to an increase in the number of crashes occurring, the National Transportation Safety Board (2006) published a major investigative report based on EMS fixed-wing and helicopter crashes between 2002 and 2005. Further, the National Transportation Board (NTSB) found that some regulations were lacking when patients were not onboard, limited use of flight risk evaluation programs, poor dispatch procedures as well as no regulations mandating the use of terrain awareness systems (p. vii).

Another aspect of air medical operations, in terms of safety, is the great deal of growth in air medical utilization. According to Isakov (2006), 650-700 air medical helicopters are currently being utilized as opposed to roughly 300 air medical helicopters in the mid 1990s. Twice as many patients are being transported via air medical helicopters utilizing twice the amount of flying hours (p. 357). In terms of growth, the air medical industry basically doubled in just over a decade. With such an increase in the air medical industry, it is crucial that safety standards as well as identifying and decreasing risk are researched and practiced. If the industry expands even more, safety issues will become more apparent and problematic.

The purpose of this research is to investigate crashes and fatalities that have resulted since 2005 when the major report was released from the NTSB. Further, factors regarding the air medical incidents such weather factors, time of day, causation, and other factors will be included as part of a comprehensive report. The goal is to find risk factors that could potentially be targeted in the future to help reduce the amount of crashes and fatalities. Data will be gathered from the NTSB and FAA databases as incidents are reported to these agencies. The study retrospective study will include rotorcraft only and include accidents from January 1, 2005 to December 31, 2011. After discovering the extent of progress being made in air medical safety, recommendations as to what safety devices, training, or best practices could help decrease the likelihood of events from reoccurring.

CHAPTER II

LITERATURE REVIEW

Identifying causes of air medical crashes is crucial to developing risk factors in order to prevent future accidents. Much research has been done in identifying risk factors as well as causes for air medical incidents. While some risk factors, such as weather or time of day, have been identified, a trend over a period of years is important to research to see if progress is being made within that specific risk. The NTSB (2006) found that 55 accidents occurred between January 2002 and January 2005 with 54 fatalities resulting from air medical crashes (p. vii). Bledsoe (2003) performed a similar research study and found that 47 accidents occurred between January 1997 and December 2001 with 40 fatalities. The rate of fatalities per crash is 0.85 (p. 94-96). The rate of fatalities per crash in the NTSB report is 0.98, which represents a 15% increase in just three years. Limiting factors to this data are that a small number of crashes could influence trends by an increase in just a few serious crashes with multiple fatalities resulting. Further, Bledsoe's data only included helicopter aircraft instead of the NTSB data that included fixed-wing medical aircraft as well. Further, investigations on differences between air medical fixed-wing and helicopter aircraft safety must be completed. In a different study, Bledsoe (2004) found that from 1993 to 2002, 52% of the fatal crashes took place in the last three years of the study (p. 1325-1326). This is a sobering fact in that air medical crashes are increasing dramatically. Bledsoe (2004) also found that air medical helicopter incidents with fatalities have been increasing in other countries as well (p. 1326). Comparatively, Sullivent, Faul, and Wald (2011) report that from 1991 to 2002, 300 fatal crashes with 357 fatalities occurred in ground ambulance operations (p. 300).

Even with numerous fatalities, ground ambulances are typically utilized much more frequently than air medical operations. Further, ground ambulances can be used in poor weather conditions whereas medical aircraft may remain grounded.

In addition to the rising number of fatalities per crash, nighttime air medical operations have been found to be extremely deadly and fatalities are on the rise. The NTSB (2006) found that out of 55 accidents, 15 fatal accidents occurred during nighttime operations, which represents 27% of total accidents but 71% of total fatal accidents. This study looked at rotor as well as fixed wing aircraft from January 2002 to January 2005 (p. vii, 26). Bledsoe (2003) had similar findings with night operation accidents accounting for 47% of all accidents with 73% of all fatalities occurring at night in 11 night operations (p. 95-96). Further, Baker et al. (2006) found that from January 1983 to April 2005 that 48% of nighttime crashes resulted in 68% of fatalities. In addition, crashes were found to occur evenly throughout the year, but fatal crashes were more likely to occur from December to February. The number of flying hours a pilot had did not influence the fatal outcome of a crash (p. 352-353). Even though nighttime crashes are more deadly than daytime crashes, more research needs to be performed into how many missions are actually being performed during nighttime to calculate a nighttime versus daytime crash rate. Baker et al. (2006) states “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” (p. 353). Weather can be difficult to study as conditions are constantly changing during an air medical mission; and, an aircraft may encounter different weather patterns during the flight. A survey of air medical helicopter pilots by Dery, Hustuit, Boschert, and Wish (2007) found that 92% of pilots felt that "pushing weather minimums" is the main cause to helicopter air medical crashes in recent years (p. 38, 41). More research into why medical aircraft are flying during borderline weather conditions is needed. Further, crashes due to weather must be identified in order to see if certain types of conditions are likely to result in a crash. It is unclear if weather is generally a cause of crashes or mostly a risk factor contributing to crashes and fatalities.

According to the NTSB (2006), air medical services operate under two different sets of regulations. 14 CFR 135 (Part 135) regulations apply to air medical operations only when a patient is onboard the aircraft. 14 CFR 91 (Part 91) regulations apply to air medical operations when no patient is onboard. Part 91 regulations are more relaxed in terms of minimum weather requirements and length of duty regulations. The NTSB found, from January 2002 to January 2005, that 35 of the 55 crashes occurred under Part 91 regulations with no patient onboard the aircraft. Further, 10 of the 55 crashes were operating under Part 91 weather requirements and fixed wing as well as rotorcraft would have been grounded due to weather if Part 135 regulations were followed (p. vii, 1-2). The NTSB promotes stricter regulations for medical aircraft operations, but it is important to note a special circumstance that may arise in air medical weather decisions. For example, even though numerous aircraft were operating under Part 91 regulations when they crashed, an air medical company is not going to send an aircraft to a scene of a car accident, in borderline Part 91 conditions, to pick up a patient knowing that the aircraft is not going to be able to take off from the scene due to the requirements of Part 135 regulations now that a patient is onboard. In a sense, an aircraft may remain grounded if Part 135 weather minimums are not met due to the fact that a patient will be onboard the aircraft for part of the mission. This allows some safety, although universal Part 135 regulations for the entire flight would provide greater safety.

Research has been conducted on stressors present for helicopter crews. Carchietti, Valent, Cecchi, and Rammer (2011) found that heart rate increases while flying in an EMS helicopter. Hypoxia due to altitude or vibrations could be a potential cause for increased heart rate (p. 272-273). Working around stressful scenes and with severely hurt or sick patients may cause an air medical crewmember to be stressed. Carchietti et al. (2011) state that "the medical crewmember under stress will tend to focus on 1 problem while ignoring other more critical information . . . commonly known as 'tunnel vision'" (p. 270). If an air medical crew is extremely concerned about getting to a scene to help a pediatric trauma patient, individuals may be mentally preparing for the scene while not thinking about safely arriving at the scene. People might take shortcuts without considering the consequences in terms of safety.

Another potential stressor is fatigue. Frakes and Kelly (2007) report that in 20% of all transportation incidents, fatigue is a factor. Pilot fatigue and the number of flight hours has not been found to affect helicopter medical crashes; but, human error has been found to be a major factor in air medical crashes that could result from fatigue (p. 46). Similarly, Bledsoe (2003) found that 70% percent of accidents involved pilot error (p. 97). If pilot error is common with the number of flight hours as a nonfactor, potentially other stressors or factors, coupled with night operations, are contributing to air medical crashes. A study on emergency physicians working during the night found decreased reaction times and a higher likelihood of skipping steps in a procedure with worsening performance as the night progressed (p. 46). This finiding could apply to a pilot or EMS crewmember in the same way as a physician. Caldwell (2001) states, “improperly managed operator fatigue can become a significant problem in environments that require alertness, complex judgment, and quick reactions, such as air EMS” (p. 25). Even though pilot fatigue has not been found to be a direct cause of EMS crashes, fatigue could be a contributing factor in making decisions when performing air medical operations.

Complacency in performing a preflight checklist as part of job duties could be a safety hazard in air medical operations. Frakes and Van Voorhis (2007) report that the National Aeronautics and Space Administration found that when humans complete a checklist, people will rely on one’s own memory, not crosschecking work when one person is reciting, combine items on the list, not finishing the checklist, or be distracted while completing the task (p. 248). Unfortunately, every industry is plagued by employee complacency; but, some industries have more at stake than others. High-risk industries, such as air medical, have little room for error. Research into sleeping patterns of pilots as well as crewmembers involved in crashes needs to be assessed to gain a better understanding of fatigue prior to an incident. Frakes and Kelly (2007) also found that 81.1% of all participants in an EMS helicopter crewmember sleep study held employment elsewhere (46-47). This information is crucial to understanding fatigue. A paramedic from an EMS ground service that worked a 24-hour shift prior to arriving at work for a 24-hour flight shift may have not had adequate rest to perform effectively or safely. Further regulations for crew rest minimums prior to arrival at work may need to established and researched.

Safety equipment for EMS helicopters could potentially help reduce the number of crashes and fatalities. The Federal Aviation Administration (FAA) (2010) advised that night vision goggles potentially allow for safer operations. The FAA states that one set of night vision goggles cost approximately $7,000 and numerous sets are needed for an aircraft. The FAA also states that some air medical operators have never had a crash at night without utilizing this safety equipment (p. 4). More research needs to be performed in this area to see the incidence of night crashes and the extent of whether or not night vision goggles are being utilized. If the devices are somewhat useful, but very expensive, then a cost analysis will need to be performed. According to Dery et al. (2007), a survey of EMS helicopter pilots revealed that night vision goggles were the top safety device needed to improve safety, and that 74% of pilots wanted their implementation (p. 38, 41). If pilots want the devices and feel that operations will become safer, research into why the devices are not being implement must take place. In the major crash report produced by the NTSB, the NTSB (2006) gives some further considerations for the use of night vision goggles. Night vision goggles cannot be utilized in urbanized areas due to ambient light. However, it was found that the use of night vision goggles would have likely prevented 13 of the 55 crashes researched in the report. The 13 accidents all involved the need to observe obstacles (p. 12-13). While some downsides are present, such as use in urban areas, night visions goggles could potentially be utilized as a tool for night operations when viewing obstacles is important. In mountainous or hilly terrain, viewing obstacles is crucial to safe operations, and night vision goggles could help in these situations. While it is easy to retrospectively criticize EMS companies or pilots for not having or utilizing safety equipment, research needs to be performed in the effectiveness of these devices as well as performing trials and collecting feedback from crews onboard the aircraft before universal implementation.

The FAA (2010) also recommends the use of terrain awareness systems. However, modifications need to be made for VFR aircraft at lower altitudes, as VFR aircraft usually fly at lower altitudes, due to the possibility of false readings (p. 5). The NTSB (2006) found in their comprehensive report that 17 of the 55 crashes could have resulted differently if terrain awareness systems had been installed. The NTSB also recommends that the FAA mandate the use of terrain awareness systems (p. 11-12). Studies must be conducted in terrain awareness systems in terms of feasibility and modification for air medical use. Potentially, an entirely different type of hazard awareness system may need to be created specifically for air medical aircraft.

Aircraft have several safety features that may help protect occupants. Tomazin, Ellerton, Reisten, Sotera, and Avbeli (2011) recommend that aircraft be outfitted with energy-absorbing seats as well as crash-resistant fuel systems (p. 337). According to Baker et al. (2006), a study about EMS crashes over more than a 20-year period found that 19% of EMS crashes resulted in a post-crash fire with 76% of the post-fire crashes resulting in fatalities. If no post-crash fire was present, 29% of crashes resulted in fatalities (p. 352-353). Clearly, post-crash fire may be a major factor into determining the survivability of a crash. More research needs to be performed to determine post-crash fire rate during nighttime operations to see if these risk factors are interrelated for fatalities. In addition, research into fire-resistant aircraft versus nonfire-resistant air medical aircraft that have crashed must be performed in order to determine occupant outcomes. Dodd (1994) reports that a study of U.S. Army helicopters revealed that 37% of fatalities resulted from post-crash fire in survivable crashes with helicopters that did not have a crashworthy fuel system while no fatalities were noted in survivable crashes with post-crash fire in helicopters that had a crashworthy fuel system (p. 284). Fire resistant safety features of an air medical aircraft could potentially save lives similar to what occurred to U.S. Army helicopters. Hawkins (1994), in a study completed by the U.S. Army Aeromedical Research Laboratory, found that in just 20 seconds after a post-crash fire, heat levels can reach 2000 degrees Fahrenheit. Most nonfire-resistant clothing will ignite in seconds, which can cause burns. This causes morbidity and mortality to increase by fourfold (p. 125). This research shows that fire-resistant clothing is crucial for EMS air medical crews to wear. Further, it shows that post-fire crashes can become extremely hot, which likely has an impact on survival. More research into how many EMS operators are utilizing protective clothing must be completed.

As landing and takeoff are critical parts of an air medical mission, it is important to understand safety techniques for takeoff and landing. On a scene flight, such as at a car accident, any form of light should be refrained from being shined into an aircraft (Tremayne, 2009, p. 12). This could interfere with the pilot from being able to see objects or hazards. Another safety feature that should be discussed is preset landing zones. Foo, Ahghari, and MacDonald (2010) state that "building and designating secure landing sites such as helipads are a potential solution to mitigate this risk [darkness, bad weather, and post crash fires] while maintaining HEMS access" (p. 461). Preset landing zones have the potential to provide a safe alternative to scene flights. These zones do not necessarily need to be paved, but just be a flat area. An ambulance service could easily designate several areas of flat land every few miles utilize as a landing zone if needed. This would aid in the familiarity for pilots landing during nighttime operations as well as provide known safe clearance. In addition, dispatch procedures would be streamlined.

More research needs to be performed in areas that have preset landing zones versus areas that do not with the resulting crash rates in those locations. Further, Robinson and Johnson (2009) state that local wind conditions can change due to buildings, such as hospitals, or other obstructions that can lead to safety hazards (p. 232). An air medical company could easily identify common wind hazards through preset landing zones. If known wind hazards are present, landing zones can be moved prior to an emergency occurs in which air medical resources are needed or training for pilots can occur if the wind hazard cannot be mitigated. While preset landing zones may decrease risk, harm to a patient may occur as well. Foo et al. found that for every 10 km a patient must travel, a 1% increase in absolute mortality resulted (p. 463). This information presents a problem that must be researched through risk assessment. If a ground ambulance must drive a patient several miles just to get to a landing zone, it could potentially harm the patient. But, a helicopter that enters a high-risk and unplanned landing zone could potentially crash, and therefore hurt the patient even more. This would need to be further researched and assessed by local terrain and obstruction agencies in a specific area.

As numerous risks have been identified, one could seemingly see how difficult it would be for an air medical service to mitigate the numerous risks, especially if they all occur at once. Thomas, Groke, and Handrahan (2011) suggest the use of preflight risk assessment scores to help identify numerous risks present in air medical operations. Risks such as "pilot experience, weather, night versus daytime operations, local versus nonlocal flights, familiar versus unfamiliar terrain, fatigue factors, and knowledge of a prior pilot turndown for same transport" (p. 49). These quick checklists allow for an expedited analysis of the situation for safety hazards. Thomas et al. (2011) further explains that scores are assigned based on hazards, which are generally created by the air medical operator. No standard values or checklists exist, but the higher the score, the greater the risk. At some services, higher scores require approval from someone outside the responding crew (p. 49). While these checklists seem a positive safety implementation, the effectiveness must be studied. It would be important to discover the perception of risk prior to an air medical crash by a crew as well as by an outside party. "Tunnel vision" could be a factor in assessment of risk for an air medical mission. The NTSB (2006) found that a flight risk program may have altered the outcome in some of the air medical crashes researched (p. 4-5). According to Thomas et al. (2011), a survey by the National EMS Pilots Association found that 90% of pilots complete a preflight assessment, but 37% found that the risk assessment was not effective in marginal weather conditions (p. 49). If pilots do not find a document to be effective, then research into why the document is ineffective as well as solutions to produce a more effective document must be found. Trust in safety practices for air medical operations are crucial. Understanding risks of air medical operations as well as understanding that numerous risks coupled together causes crashes with resulting fatalities. Checklists may be able to help identify numerous risks quickly that people mentally cannot assess together at the same time. Thomas et al. (2011) state that "one of the most cost-effective means of reducing accidents may not be the ready acceptance and implementation of expensive technology or training but rather the acceptance and implementation of reliable and validated risk assessment scores" (p. 53). More studies in the accuracy of that statement need to take place, but sometimes, small measures can make a huge difference in terms of a safety culture. Development needs to take place of a universal preflight risk assessment. Further, deviation from that checklist needs explanations. While one checklist may not fit every operation, it should, generally speaking, give a general idea of the level of risk for most situations. It would be important for researchers to assess risks present prior to crashes that have already occurred and develop a risk analysis to help mitigate future incidents.

Air medical safety and crash research is complex and data can sometimes be challenging to obtain. If obtainable, most research is only on a single topic, and performed only once. The air medical industry is still developing and is being utilized in different forms throughout different areas of the country. Further, different areas of the country have different uses and hazards for the air medical industry. Air medical crashes with resulting fatalities and nonfatalities must be reduced in order to provide safe transport of EMS crews and the critical patients they serve.

CHAPTER III

THEORETICAL FRAMEWORK

Understanding risks and how risks are increased or decreased over time is crucial to conducting safe air medical operations. Research into government investigative reports provides relatively unbiased information. This investigative data has been thoroughly researched in regard to air medical incidents. As numerous incidents are researched, compiled data will begin to show certain features of high risks that lead to incidents as opposed to other features of low risk. Low risks must be analyzed to make sure that low risks do not become high risks. High risks must be lessened through mitigation strategies, risk management, and awareness. The goal with high risks is to make them low risks or even no risk. While several risks have been noted, it is important to note that these risks may have changed over the past few years. This study will hopefully find those risks that have become more or less likely to occur. Some risks may have remained the same as time has progressed. The critical point is that unidentified risks could potentially cause harm to patients, flight crews, and innocent bystanders. In terms of analysis, risks that are found to have increased risk for fatalities should be identified. This data will be analyzed according to the following research questions:

- Is there a statistical significance between day and night incidents and whether or not a fatality occurred?
- Do Part 91 or Part 135 regulations have a statistically higher number of fatal crashes?
- Do certain operations, such as takeoff/landing or en route, have a significant relationship to fatalities?

- Do post-crash fires result in a higher likelihood of fatalities?
- Is there a statistical significance between pilot hours and fatal incidents?
- Does an aircraft have significantly more fatal outcomes flying from VFR to IFR conditions than an aircraft simply flying into its originally set conditions (VFR or IFR)?

If numerous risks contribute to fatalities, then several approaches might need to be implemented in order to decreased fatal outcomes. Risks that are identified to contribute to or cause incidents can then be implemented into an air medical safety program to allow for safer operations. Followed by safety program adjustments and implementation, research is then performed in order to understand the extent of effectiveness of the safety programs and risk management activities. The degree of the risk might change every time research is performed as technology, legislation, and practices change within the air medical industry. This creates a continuous process to try and eliminate air medical incidents through risk identification and mitigation.

CHAPTER IV

RESEARCH METHODOLOGY

This retrospective cross-sectional descriptive study will analyze quantitative data from past air medical incidents. Due to the fact that this study utilizes retrospective reports and no human subjects are utilized, this study is IRB exempt. The research will consider incidents that occurred from January 1, 2005 to December 31, 2011.

Initial research will include identification of air medical incidents. This will be identified by utilizing a NTSB database. The NTSB Aviation Accident Database & Synopses allows an individual to view accident reports. The NTSB Aviation Accident Database & Synopses will be utilized to research helicopter crashes and events. The database includes factual information, probable causes, and preliminary reports. As much of this data will be included as possible, but only if tentative information is included, will it be noted in the results. Key words such as "air medical", "HEMS", "flight paramedic", and "flight nurse" will be entered into the NTSB Aviation Accident Database & Synopses to discover air medical incidents that resulted in victims or damage to an aircraft. Events in which at least one injury or fatality occurs will be criteria for inclusion in the study. An accident will be included in the study if an injury or fatality occurs to an occupant within the aircraft or if the aircraft is substantially damaged or destroyed. To determine whether or not an aircraft is substantially damaged or destroyed, the aircraft damage level will be recorded as it is reported within the NTSB accident report. Injury data is obtained from NTSB accident reports as well. Aircraft must be operating under Part 91 or Part 135 regulations to be included. This study will only include rotorcraft. This is due to the fact that a rotorcraft can land on a highway or field for an air medical incident. A fixed-wing aircraft can only land at an airport, which becomes difficult to include within this type of research. Both instrument flight rules (IFR) as well as visual flight rules (VFR) will be included in the research study. Training as well as maintenance flights will be included. Government aircraft will not be included. People that are injured on the ground will not be included within the study. The injuries must occur to people on the aircraft.

From these databases, information will be recorded in a Microsoft Excel spreadsheet. The variables that will be assessed are under the following headings are: General Information, Occupant Outcomes, NTSB Report Information, Aircraft/Pilot, Weather, and Other Information. General Information includes data such as time and date. Night versus daytime accidents are recorded on the NTSB accident report. If no day/night designation is given, night will be considered 1900 to 0700. If dusk is reported as a light condition, then it will be reported as night. Occupant Outcomes assess how many people were injured and what severity of injury. The NTSB Report Information section includes information such as regulations the aircraft was operating under at the time of the incident and whether or not a post-crash fire was present. Investigation into what task, such as takeoff or landing, the aircraft was performing at the time of the incident is the main goal of data collection in this section. Within the Aircraft/Pilot section, data relating to the type of aircraft as well as the number of pilot hours will be documented. The Weather section strives to get a glimpse as to what types of weather was occurring during the incident. Only basic weather information will be gathered in this section. The Other Information section will be utilized to give a brief synopsis of the incident for further reference if needed.

Several limitations exist in the study. Due to the nature of ongoing investigations, some data, even from several years ago, is still not finalized. Data, from 2011 for instance, may not be fully accurate due to ongoing investigations and all reports may not be finalized and could even be modified as investigations continue. This data will still be utilized and absorbed as a risk within the results of the research. Further, data that has been recorded could potentially be inaccurate. The research relies on reports that are created by one agency, the NTSB, with individuals conducting investigations. It is possible that investigators are biased towards certain findings, such a pilot error. While it is plausible that investigators try to remain as unbiased as possible, the possibility still exists that the information as documented in investigations is inaccurate or biased. One investigator may view potential causes of an incident differently than another. Further, data may be entered into a report incorrectly. This will be accepted as potential flaws in data collected due to the fact that the research cannot control for this type of bias. In addition, not all reports may be filled out completely. This data will be represented with a "N/A" within the data spreadsheet. If certain data collections have a great deal of missing data, statistical analysis will not be performed. Due to the competitive air medical industry, bias will be minimized by not providing or recording the air medical provider or company. The goal of this research is not to determine which air medical company provides the best or safest services. Finding which company has more serious incidents only strives to improve those entities. This research looks to improve within the air medical industry as a whole.

CHAPTER V

ANALYSIS

After data is recorded within the Mircosoft Excel 2008 (2007) spreadsheet, this data will be analyzed by importing specific data into IBM SPSS Statistics version 21 (2012) where statistical significance will be tested. Some data will be analyzed in Microsoft Excel as well. Means, standard deviations, frequencies, and percentages were reported as appropriate. Bivariate analyses include Chi-square tests for association, independent sample t-tests, and Mann-Whitney U tests. A significance level of alpha=.05 was used throughout.

CHAPTER VI

RESULTS

Of the 68 reported incidents, 28 (41%) incidents resulted in at least one fatality. Five reports had only preliminary information (7%). For incidents reporting fatalities, the median number of fatalities was 3 (min = 1, max = 4). In all incidents, the median number of fatalities was 0 (min = 0, max = 4). Seventy two percent of all fatal crashes involved 3 fatalities or more. In terms of comparing medians among fatal incidents, thirty six percent of fatalities occurred during the day while 64% occurred at night. Even though more fatalities occurred during the night, there was no statistical significant difference between time of day and median number of fatalities (median night fatalities = 3, median day fatalities = 3, $p = 0.5$).

Sixty-four percent of fatalities were operating under Part 91 regulations, while only 36% were operating under Part 135 regulations. If the number of fatalities (min = 1, max = 4, median Part 91 fatalities = 3, median Part 135, fatalities = 3.5) are measured against Part 91 and Part 135 regulations, Part 91 regulations were more likely to result in a fatality ($p = 0.04$). Sixty eight percent of all nonfatal incidents occurred under Part 91 regulation while 33% occurred under Part 135 regulations. No significance was noted ($p = 1.0$) between nonfatal Part 91 and Part 135 incidents.

In terms of flight operations, takeoff/landing resulted in 9 incidents (33%) in which at least one fatality occurred. Nineteen incidents (68%) resulted in a fatal incident in which the helicopter was en route. No significance in number of fatalities was noted between incidents of taking off/landing versus number of fatalities (median takeoff/landing fatalities = 3, median en route fatalities = 3, $p = 0.1$). In terms of all 68 nonfatal and fatal incidents, takeoff/landing had 63% of all incidents while en route had 37% of all incidents.

In terms of post-crash fire with fatalities, 15 incidents (54%) had a post-crash fire. In terms of number of fatalities (min = 1, max = 4) and post crash fire, no significance (median fatalities in no post-crash fire = 3, median fatalities in post-crash fire = 3, p = 0.9) was noted. A total of 3 incidents resulted in post-crash fire in which there were no fatalities.

The mean number of pilot hours (only rotorcraft) for all recorded (n = 52) incidents was 6078 hours (SD = 3830.096). The mean rotorcraft pilot hours for 20 fatal incidents was 6018 hours (SD = 4613.717) whereas the mean for 32 nonfatal incidents was 6115 hours (3329.217). In terms of fatal or nonfatal incidents, no significance was noted between these variables (p = 0.935).

In terms of visual and instrument flight conditions, 17 fatal (min = 1, max = 4), incidents involved similar conditions whereas 7 events resulted in changing conditions. No significance was noted in terms of the number of fatalities and changing or constant conditions (median VFR to IFR fatalities = 3, median constant conditions = 3, p = 0.601).

Table 1 includes information about specific categories and their resulting numbers and percentages while Table 2 includes information about which incidents were included and number of fatalities.[1]

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[1] See Appendix A for Table 1 and Appendix B for Table 2

CHAPTER VII

DISCUSSION

From the results of this study, several risks were apparent in terms of statistical significance. One of the major risks noted in the findings of this research was the fact that Part 91 regulations are statistically more likely to result in more fatalities as opposed to Part 135 regulations. Part 91 regulations are more lenient than Part 135 regulations in that Part 91 regulations are conducted without a patient on board the aircraft. Further, this study found that the median number of fatalities was 3. This is important in that most air medical operators have three crewmembers, one pilot and two medical personnel, on board the aircraft. With this crew arrangement, the aircraft can fly under Part 91 regulations. Further, the median shows that air medical crews are being killed as opposed to a patient being on board the aircraft in addition to the crew. Positioning the aircraft to pick up a patient or after a patient is dropped off at the hospital are typically when Part 91 regulations are being utilized. As reported in the literature review, the NTSB (2006) had similar findings in incidents with Part 91 regulations resulting in more crashes. In terms of risk assessment and incident prevention, an air medical flight that follows Part 135 regulations could potentially be safer. More research into Part 135 and Part 91 regulations must take place before a major decision such as changing to air medical aircraft only flying in Part 135 regulations is put into place.

Interestingly, no significance was noted between day and nighttime incidents with the number of fatalities. Even with no statistical significance, more fatal incidents, by percentage, occurred during night. Lots of risk management programs have targeted nighttime flights in order to make air medical operations in low light conditions safer.

The use of night vision goggles is a great benefit and tool for air medical services. Night vision goggles provide some risk mitigation. Even with some risk mitigation, night vision goggles are extremely expensive and several incidents within this study resulted in misuse of night vision goggles. Training is critical to making sure that new safety implementations are appropriately utilized. While this research was not conducted to directly assess the use of night vision goggles, it is worth reporting for potential studies in the future.

In terms of the number of pilot hours and incident outcome, no significance was found. This finding is similar to what Frakes and Kelly (2007) found as well. Further, air medical pilot experience is very high as well. This is important for air medical services to realize. With the extreme growth (Isakov, 2006), air medical companies must not sacrifice pilot experience in terms of hiring pilots.

Post-crash fire produces some intriguing findings. Baker et al. (2006) found that post-crash fire produced more fatal outcomes. Within this study, it was found that about half of all fatal incidents resulted in post-crash fire. Baker et al. (2006) found a much higher rate of fatalities in post-crash fire. It is possible that post-crash fires in fatal incidents are being reduced through safety systems on aircraft or personal protective equipment for flight crews. It is also possible that fatal impacts are more likely to be the cause of death instead of post-crash fires. More research in this area must be performed prior to making any changes.

An interesting finding is the operation of the aircraft at the time of the incident. Over two thirds of all fatal air medical aircraft incidents resulted while the aircraft was en route from location to location. Typically, takeoff and landing is regarded to be the more critical time where an incident may occur. Installation of terrain awareness systems as well as continued use of night vision goggles could potentially mitigate this risk. In terms of all incidents, fatal and nonfatal, it was significantly more likely for an incident to occur while the aircraft was taking off or landing. Further risk mitigation must take place while the aircraft is en route to a destination in order to prevent fatalities.

In terms of weather, 25% of all fatal incidents involved changing conditions (VFR to IFR). While this was not statistically significant, it is important to realize that IFR instruments may provide some safety and therefore risk mitigation. One downside to installing IFR instrumentation on air medical aircrafts is that it can be extremely expensive. Further, pilots must be trained in IFR instrumentation. This can be costly as well. A risk analysis must be performed by the air medical service prior to investing in IFR capabilities. The investment in IFR pilot training and IFR aircraft is that the aircraft would be better able to divert safely from unexpected IFR conditions. Again, cost analysis is key to IFR capabilities as different areas in the United States have differing weather conditions.

CHAPTER VIII

CONCLUSION

This study found that some air medical risks appear to be decreasing while others remain unchanged. In terms of further risk mitigation, it is important to perform a cost analysis in order to determine what safety programs and equipment should be acquired in order to provide the greatest safety for the lowest cost. Unfortunately, the air medical industry has high capital expenditures and is extremely competitive. Safety of patients, crewmembers, and bystanders should take priority over financial gains. Further, continued research into risks for air medical incidents should be further discussed. As risks change over time, a risk could easily be disregarded or not known without further research and therefore a strategy to prevent a tragedy go untouched. Risk assessment within the air medical industry is vital to save lives and provide the best possible care to patients that need it the most.

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APPENDIX A

Number and Percentage of Fatal/Nonfatal Incidents in Categories Tested

Table 1
Number and Percentage of Fatal/Nonfatal Incidents in Categories Tested

Category	Number (n=68)	Percent
Nonfatal	40	58.8
Fatal	28	41.2
1 Fatality	5	7.4
2 Fatalities	3	4.4
3 Fatalities	15	22.1
4 Fatalities	5	7.4
Day	27	39.7
Nonfatal	17	42.5
Fatal	10	35.7
Night	41	60.3
Nonfatal	23	57.5
Fatal	18	64.3
Part 91	45	66.2
Nonfatal	27	67.5
Fatal	18	64.3
Part 135	23	33.8
Nonfatal	13	32.5
Fatal	10	35.7
Post-crash Fire		
Fatal (Yes)	15	53.6
Fatal (No)	13	46.4
Nonfatal (Yes)	3	7.5
Nonfatal (No)	36	90.0
Takeoff/Landing	43	63.2
Nonfatal	34	85.0
Fatal	9	32.1
En Route	25	36.8
Nonfatal	6	15.0
Fatal	19	67.9
VFR to IFR	8	11.8
Nonfatal	1	2.5
Fatal	7	25.0
Constant FR	48	70.6
Nonfatal	31	77.5
Fatal	17	60.7
Pilot Hours		Mean
Fatal	20	6018.35
Nonfatal	32	6115.38

Note: This table represents each individual category tested within the study followed by the percentage and number. Pilot hours are described as a mean and is noted above.

APPENDIX B

Location and Date of Incidents Studied with Resulting Fatalities

Table 2
Location and Date of Incidents Studied with Resulting Fatalities

Location	Date	Fatalities
Casa Grande, AZ	3-Jan-05	0
Falkner, MS	5-Jan-05	1
Oxon Hill, MD	10-Jan-05	2
Pilar, NM	29-Jan-05	0
Gentry, AR	21-Feb-05	1
Mancos, CO	30-Jun-05	3
West Plains, MO	13-Jul-05	0
Valparaiso, IN	14-Jul-05	0
Jacksonville, FL	14-Aug-05	0
Edmonds, WA	29-Sep-05	3
Smethport, PA	7-Oct-05	1
Olympia, WA	28-Oct-05	0
Robbinsdale, MN	8-Nov-05	0
Kalispell, MT	2-Jan-06	0
Ponce, PR	12-Jan-06	0
Port Isabel, TX	26-Jan-06	0
Chesterfield, IN	2-Feb-06	0
Green Bay, WI	13-Apr-06	1
Bonifay, FL	21-Apr-06	0
Washington, DC	30-May-06	1
Ponce de Leon, FL	22-Jun-06	0
Casa Grande, AZ	27-Aug-06	0
Brownwood, TX	26-Nov-06	0
Hesperia, CA	10-Dec-06	3
Isla de Vieques, PR	27-May-07	0
Marks, MS	28-Jul-07	0
Ridgeville, SC	9-Aug-07	0
Mullinville, KS	22-Aug-07	0
Talladega, AL	1-Dec-07	0
Whittier, AK	3-Dec-07	4
Cherokee, AL	30-Dec-07	3
DeLand, FL	7-Jan-08	0
S. Padre Island, TX	5-Feb-08	3
La Crosse, WI	10-May-08	3
Grand Rapids, MI	29-May-08	0
Pottsville, PA	30-May-08	0
Huntsville, TX	8-Jun-08	4
Ash Fork, AZ	27-Jun-08	0

Note: This table represents the incidents included in the study with resulting fatalities.

Table 2 (continued)

Location	Date	Fatalities
Flagstaff, AZ	29-Jun-08	3
Flagstaff, AZ	29-Jun-08	4
Greensburg, IN	31-Aug-08	3
Aurora, IL	15-Oct-08	4
Cave Creek, AZ	22-Feb-09	0
Gainsville, FL	5-Mar-09	0
Loris, SC	2-Jul-09	0
North Captiva Island, FL	17-Aug-09	0
Tucson, AZ	24-Sep-09	0
Georgetown, SC	25-Sep-09	3
Blythe, CA	22-Oct-09	0
Doyle, CA	14-Nov-09	3
Decatur, TX	25-Dec-09	0
Reno, NV	17-Jan-10	0
El Paso, TX	5-Feb-10	3
Brownsville, TN	25-Mar-10	3
Santa Maria, CA	9-Apr-10	0
Midlothian, TX	2-Jun-10	2
Kingfisher, OK	22-Jul-10	2
Tucson, AZ	28-Jul-10	3
Walnut Grove, AR	31-Aug-10	3
Riverdale, UT	22-Nov-10	0
La Monte, MO	19-Dec-10	0
Cherry Point, NC	29-Dec-10	0
Albert Lea, MN	1-Jan-11	0
Camden, SC	3-May-11	0
Troutdale, OR	27-Jul-11	0
Mosby, MO	26-Aug-11	4
Carbondale, IL	13-Nov-11	0
Green Cove Springs, FL	26-Dec-11	3

Note: This table represents the incidents included in the study with resulting fatalities.