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# **Medical Helicopter Accident Review: Causes and Contributing Factors**

Richard Greenhaw  
Mehdi Jamali, Venesco LLC

Civil Aerospace Medical  
Institute Federal Aviation  
Administration  
Oklahoma City, OK 73125

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Final Report

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<p><b>16. Abstract</b></p> <p>The purpose of this study was to determine the quantitative differences in Emergency Medical Service (EMS) and non-EMS helicopter accident rates and trends by examining accident reports of both fatal and non-fatal accidents. The study also aimed to identify contributing factors or conditions that result in either fatal or non-fatal helicopter accidents.</p> <p>This was a retrospective, longitudinal observational study that examined more than 3,000 EMS and non-EMS helicopter accident records covering 20 years beginning in 1999 provided by the National Transport Safety Board and analyzed their data using linear and multivariate logistic regression models along with statistical hypothesis tests to predict trends and associations. This study found that fatal accidents accounted for a much higher proportion of EMS helicopter accidents than non-EMS accidents (rates for non-EMS helicopter accidents were essentially twice that for EMS accidents), and the rates for fatal helicopter accidents did not differ between EMS and non-EMS. Additionally, the study found two prevalent factors that determined EMS accident fatality: visibility/darkness and pilot decision making/judgment. Additional factors highly associated with fatal EMS accidents were pilots with a second-class medical certificate rather than first-class and the lack of a second pilot.</p> <p>Exploring the reasons for the much higher proportion of fatal EMS vs. non-EMS accidents is outside the scope of this study. Such questions could be the subject of further research. Detailed analyses focusing on this research could lead to a reduction in fatal EMS accident rates.</p>					
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**LIST OF ACRONYMS**

CI.....	Confidence Interval
ELT.....	Emergency Locator Transmitter
EMS.....	Emergency Medical Service
FAA.....	Federal Aviation Administration
GVIF.....	Generalized Variance Inflation Factor
HEMS.....	Helicopter Emergency Medical Service
IRB.....	Institutional Review Board
NTSB.....	National Transport Safety Board
OR.....	Odds Ratio

## EXECUTIVE SUMMARY

The purpose of this study was to determine the quantitative differences in Emergency Medical Service (EMS) and non-EMS helicopter accident rates and trends by examining accident reports of both fatal and non-fatal accidents. The study also aimed to identify contributing factors or conditions that result in either fatal or non-fatal helicopter accidents.

This was a retrospective, longitudinal observational study that examined more than 3,000 EMS and non-EMS helicopter accident records covering 20 years beginning in 1999 provided by the National Transport Safety Board and analyzed their data using linear and multivariate logistic regression models along with statistical hypothesis tests to predict trends and associations. This study found that fatal accidents accounted for a much higher proportion of EMS helicopter accidents than non-EMS accidents (rates for non-EMS helicopter accidents were essentially twice that for EMS accidents), and the rates for fatal helicopter accidents did not differ between EMS and non-EMS. Additionally, the study found two prevalent factors that determined EMS accident fatality: visibility/darkness and pilot decision making/judgment. Additional factors highly associated with fatal EMS accidents were pilots with a second-class medical certificate rather than first-class and the lack of a second pilot.

Exploring the reasons for the much higher proportion of fatal EMS vs. non-EMS accidents is outside the scope of this study. Such questions could be the subject of further research. Detailed analyses focusing on this research could lead to a reduction in fatal EMS accident rates.

# **MEDICAL HELICOPTER ACCIDENT REVIEW: CAUSES AND CONTRIBUTING FACTORS**

## **INTRODUCTION**

Helicopter Emergency Medical Service (HEMS) is the most common means of air medical transport in the United States (US), with over 400,000 patients flown each year (Huber, 2018). HEMS has a diverse set of advantages over ground-based emergency medical services (EMS) transport, such as flexibility in motion, access to remote locations, and reduced transport times. Several studies have demonstrated that HEMS can have a noticeable advantage over ground EMS. For instance, Andruszkow et al. (2013) analyzed the transportation data of 13,220 trauma patients in Germany and demonstrated that HEMS patients' trauma center survival odds were significantly higher than those of ground EMS patients. It is, therefore, unsurprising that HEMS has become a \$2.5B industry in the US (Widmeier, 2014).

While HEMS are becoming somewhat safer, safety concerns still exist. Extensive adoption of night-vision goggles, weather regulatory improvements, and Terrain Awareness Warning Systems implementation may have led to a decrease in HEMS accidents (MacDonald, 2010). However, even after the widespread adoption of night-vision goggles, most fatal HEMS accidents (i.e., HEMS accidents with at least one fatality) continue to occur at nighttime (Huber, 2016). In addition, the percentage of fatal accidents is much higher for HEMS than for non-HEMS operations. These concerns indicate that studying the contributing factors of HEMS mishaps can be a useful element in reducing the safety risks for HEMS pilots, crewmembers, and patients.

Accidents of helicopters in general and HEMS specifically have been the topic of several studies in recent decades. Baker et al. (2006) examined contributing factors in fatal HEMS crashes by reviewing 182 HEMS accidents from 1983 to 2005, acquired from the National Transportation



Safety Board (NTSB). Their multivariate logistic regression analysis revealed that post-crash fire, adverse weather, and darkness increased the odds of a fatal outcome. Voogt and van Doorn (2007) reported that adverse weather, recorded as Instrument Meteorological Conditions, and flying near stationary objects were the most prevalent causes of fatal helicopter accidents. They also noted that lower altitude accidents were less likely to be fatal than higher altitude accidents. Also, de Voogt (2011) studied the contributing factors of accidents at night by reviewing 4,755 helicopter accidents. That study found that mechanical error had a lesser association with nighttime helicopter accidents than daytime accidents, and the combination of severe weather conditions and night flights increased the odds of fatal accidents (de Voogt, 2011).

Furthermore, Low et al. (1991) compared different groups of EMS helicopter programs and concluded that busy programs had an eight-times lower chance of accidents than less active programs. They also found that flight capability under Instrument Flight Rules was a significant factor in decreasing the chance of mishaps. This finding, supported by the more recent work of Holland and Cooksley (2005), also implicated HEMS night missions under Visual Flight Rules as posing a higher risk of accidents.

In addition, Huber (2016) studied 222 HEMS accidents from 1998 to 2016 and found that the primary contributing factors were human factors (94%), weather conditions (25%), controlled flight into terrain (21%), and landing issues (9%).

While these studies have examined contributing factors for helicopter accidents in general and fatal HEMS and non-HEMS accidents, no published study has compared EMS with non-EMS helicopter accidents (fatal or non-fatal). In addition, no published study has examined the relationship between EMS and non-EMS helicopter accident rates and contributing factors over time. This study aims to fill those gaps.

This study examined potential contributing factors and longitudinal trends over the last two decades. Understanding the differences between the factors contributing to EMS and non-EMS helicopter accidents and how these have changed over time can assist policymakers in their decision-making. To achieve this goal, this study addressed the following general questions: 1) What are the differences, if any, in rates between EMS and non-EMS helicopter accidents? 2) How have these rates changed over time? 3) What are the differences, if any, in contributing factors and conditions between EMS and non-EMS helicopter accidents? 4) What are the differences, if any, in contributing factors and conditions between fatal and non-fatal EMS helicopter accidents? Specifically, the study will attempt to accept or reject these related hypotheses<sup>1</sup>:

- i. The number of EMS (non-EMS) helicopter accidents per year has not remained constant.
- ii. The number of fatal EMS (non-EMS) helicopter accidents per year has not remained constant.
- iii. The ratio of fatal to all EMS (non-EMS) helicopter accidents per year has not remained constant, and the EMS and non-EMS ratios are not the same.
- iv. The number of EMS (non-EMS) helicopter accidents per flight hour has not remained constant.
- v. The number of fatal EMS (non-EMS) helicopter accidents per flight hour has not remained constant.
- vi. The number of EMS and non-EMS helicopter accidents per flight hour is not the same.

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<sup>1</sup> These hypotheses cover 1999 through 2018 except that the hypotheses involving flight hours do not include 2018 because accurate flight hour values were not available. In addition, hypothesis viii covers only the 10-year period from 2008 through 2017 because the NTSB database includes data describing contributing factors only for events after 2007. The first five hypotheses are double hypotheses, one for EMS helicopter accidents and one for non-EMS helicopter accidents. Hypotheses i and ii refer to accident counts rather than rates and are presented as background information.

- vii. The number of fatal EMS and non-EMS helicopter accidents per flight hour is not the same.
- viii. The proportion of each contributing factor identified is not the same for fatal EMS and non-EMS helicopter accidents.
- ix. The odds of each condition or factor identified is not the same for EMS and non-EMS helicopter accidents<sup>2</sup>.
- x. The odds of each condition or factor identified is not the same for fatal and non-fatal EMS helicopter accidents.

## **METHOD**

Data for this study were retrieved from NTSB aviation event reports (reports of both incidents and accidents). Because all human data used in this study came from the publicly available NTSB Aviation Accident database, the appropriate Federal Aviation Administration Institutional Review Board (IRB) deemed this study exempt from IRB approval requirements. NTSB is an independent government agency authorized to investigate all aircraft events, including incidents and accidents. NTSB reports provide an extensive set of details regarding event time, date, location, aircraft type, pilot and crew members, light and weather condition, inspection records, and dozens of other parameters. These parameters, intended to describe the background and environment of the accident rather than its contributing factors or causes, are referred to as *conditions* in this study. NTSB reports also provide the factors that investigators list as accident causes and contributing factors. For simplicity, this study will use the single term *factor* to refer to what the NTSB notes as causes and contributing factors. For this study, all events from 1999 to 2018 were retrieved from

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<sup>2</sup> This hypothesis differs from the previous in that it applies to both conditions and factors as opposed to just contributing factors.

the NTSB Aviation Accident Database. From these data, only helicopter events that occurred in the US were retained (AIRCRAFT:acft\_category = "HELI")<sup>3</sup>. Of those, events involving homebuilt (AIRCRAFT:homebuilt = "N") or military (AIRCRAFT:acft\_reg\_cls = anything but "MIL") helicopters were removed from the data. In addition, any incidents (i.e., occurrences defined as near-miss events) were removed from data, leaving only accidents (EVENT:ev\_type = "ACC"). Then, based on the value of the NTSB database EMS parameter (AIRCRAFT:air\_medical = "Y" or "N"), the remaining accidents were divided into two groups: EMS helicopter (206 accidents) and non-EMS helicopter (2,832 accidents). In addition, based on these NTSB data and usage data from the Federal Aviation Administration Part 135 Activity Survey (Federal Aviation Administration, 2019), rates of EMS and non-EMS helicopter accidents per 100,000 flight hours were calculated for fatal and non-fatal accidents for 1999 through 2017. Because the NTSB database includes data describing causal and contributing factors only for events after 2007, the specific analyses involving those factors cover only events since that year (i.e., events occurring from 2008 through 2018).

These factors (contributing and causal factors) of helicopter accidents were grouped into 10 factor groups: (1) Aircraft/Mechanical, (2) Visibility/Darkness, (3) Other Weather, (4) Object/Terrain Encounter, (5) Organizational Compliance, (6) Pilot Decision Making/Judgment, (7) Pilot Experience, (8) Pilot Incapacitation, (9) Pilot Attention/Orientation Issues, and (10) Pilot Flight Preparation. This grouping was used to present the basic types of contributions and causes clearly, given that there are hundreds of specific contributing and causal factors associated with

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<sup>3</sup> Where appropriate, specific variables from the NTSB Aircraft Accident Database are cited. These variables are describe using the format TABLE:variable = "value". Where TABLE is the database table name, variable is the variable name within the table, and "value" is the value of the variable on which the selection is based.

accidents in the NTSB data. The grouping was accomplished using an objective method, which is described in detail in the Appendix.

Various statistical methods were used to describe and analyze accident rates, factor prevalence, and condition likelihoods. Accident rates were displayed using bar charts and scatter plots and analyzed using linear regression for trends and paired t tests for comparisons. Accident factor relationships were displayed using bar charts and were analyzed using chi-square tests.

A multivariate logistic regression model, Model 1, was developed for all helicopter accidents occurring from 2008 to 2018 to compare the conditions and factors between the two groups (EMS and non-EMS helicopter accidents). In this model, the binary response variable value was either EMS helicopter or non-EMS helicopter. Due to the interconnectedness of the predictors (conditions) such as aircraft size and mission, light and weather conditions, and time of the year, multicollinearity between parameters was checked. Based on the suggestion of Fox and Monette (1992), a variable selection process was developed based on the Generalized Variance Inflation Factor (GVIF) to avoid the collinearity of the parameters. An iterative process was executed until only variables with GVIF lower than 2.5 (a predefined cutoff value) remained in the model. These were the remaining predictor variables: findings category (i.e., the 10 abovementioned factors), number of engines (i.e., one or multiple), airframe hours since the last inspection, presence of a second pilot, Emergency Locator Transmitter (ELT) installed, pilot medical classification, and operator same as owner.

Another model, Model 2, was developed to analyze the fatal and non-fatal EMS helicopter accidents to help identify the difference in conditions and factors, if any, between fatal and non-fatal EMS accidents. The model's binary response variable had the following values: fatal EMS helicopter and non-fatal EMS helicopter. The predictors (conditions and factors) for Model 2 were

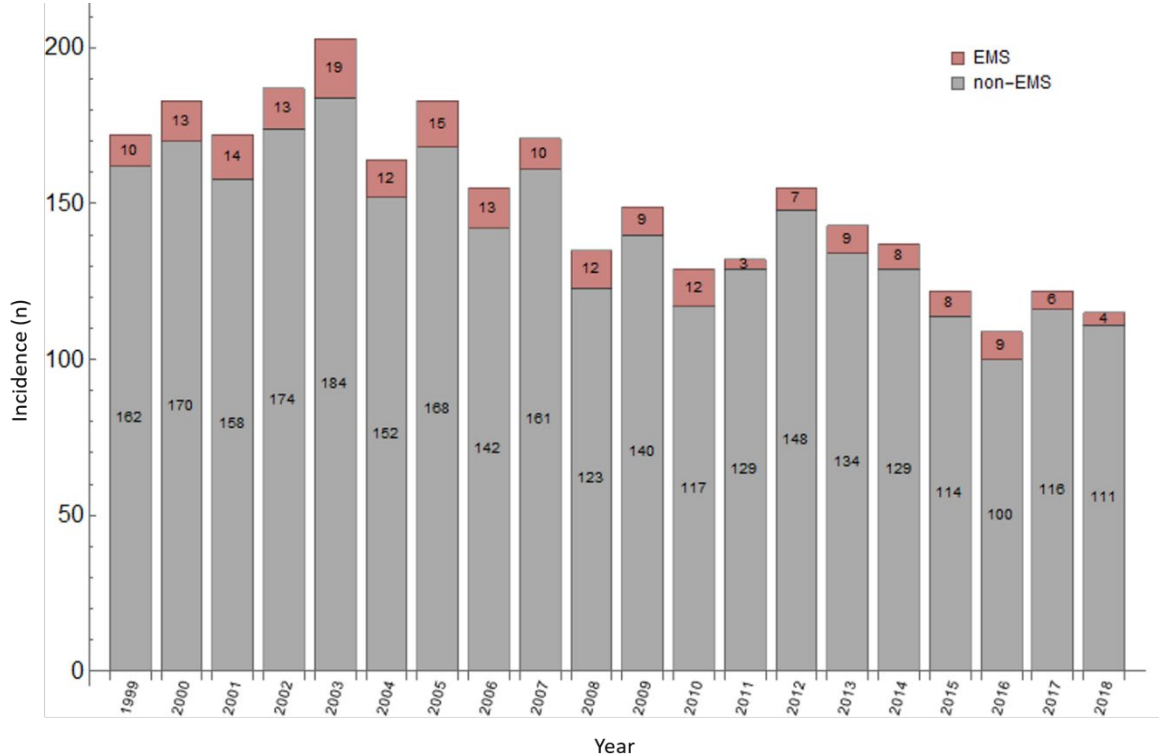
the number of engines (i.e., one or two), airframe hours since the last inspection, presence of a second pilot, ELT installed, operator same as owner, and primary medical certificates of the pilot (first-, second-, or third-class).

To confirm their validity, all models were tested by Hosmer-Lemeshow and Pearson goodness-of-fit tests with p-value  $> 0.10$ . All hypothesis tests were evaluated at significance level  $\alpha = 0.05$ . Analyses were performed using Wolfram Mathematica Version 11.0.

## RESULTS

Figures 1 through 10 summarize non-EMS and EMS helicopter accident rates and trends. As shown in Figure 1, in the 20 years from 1999 to 2018, there were 2,832 non-EMS helicopter and 206 EMS helicopter accidents in the US. As shown in Figures 1 and 2, EMS counts for all helicopter accidents were much lower than non-EMS counts (means: 10.3 and 141.6, respectively; 95% confidence intervals [CIs]: 8.62 to 11.98 and 131.07 to 152.13, respectively). For their linear regression models, the p-values < 0.01 for both indicate that the null hypotheses (i.e., the linear slopes are zero) should be rejected in favor of the alternative hypotheses that the slopes are non-zero (they are, in fact, negative). Thus, accident counts for both EMS and non-EMS show declining trends over the 20-year study period.

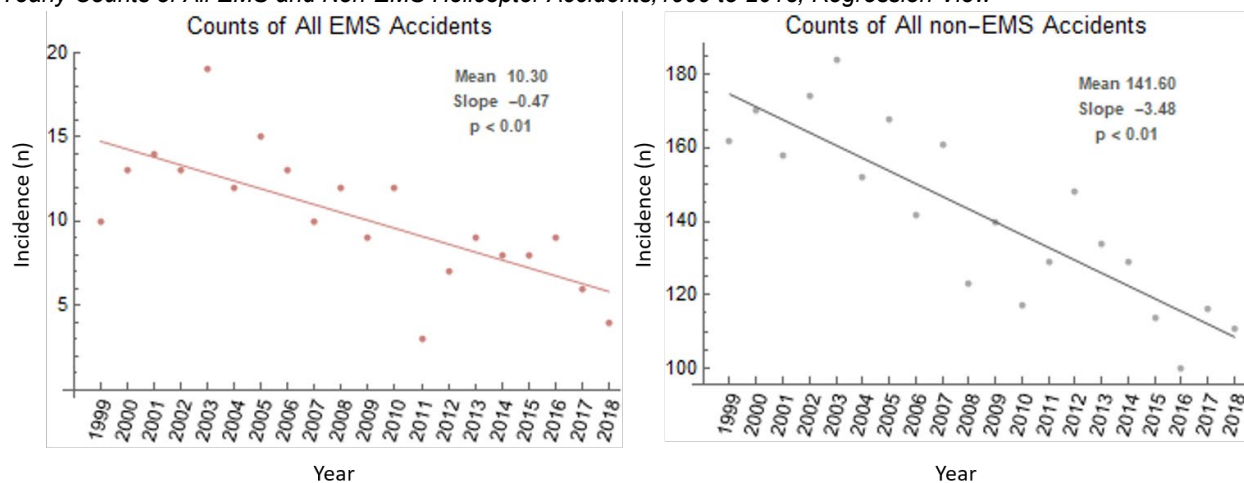
**Figure 1**  
*Yearly Counts of All EMS and Non-EMS Helicopter Accidents From 1999 to 2018*



*Note.* EMS = emergency medical service.

**Figure 2**

Yearly Counts of All EMS and Non-EMS Helicopter Accidents, 1999 to 2018, Regression View

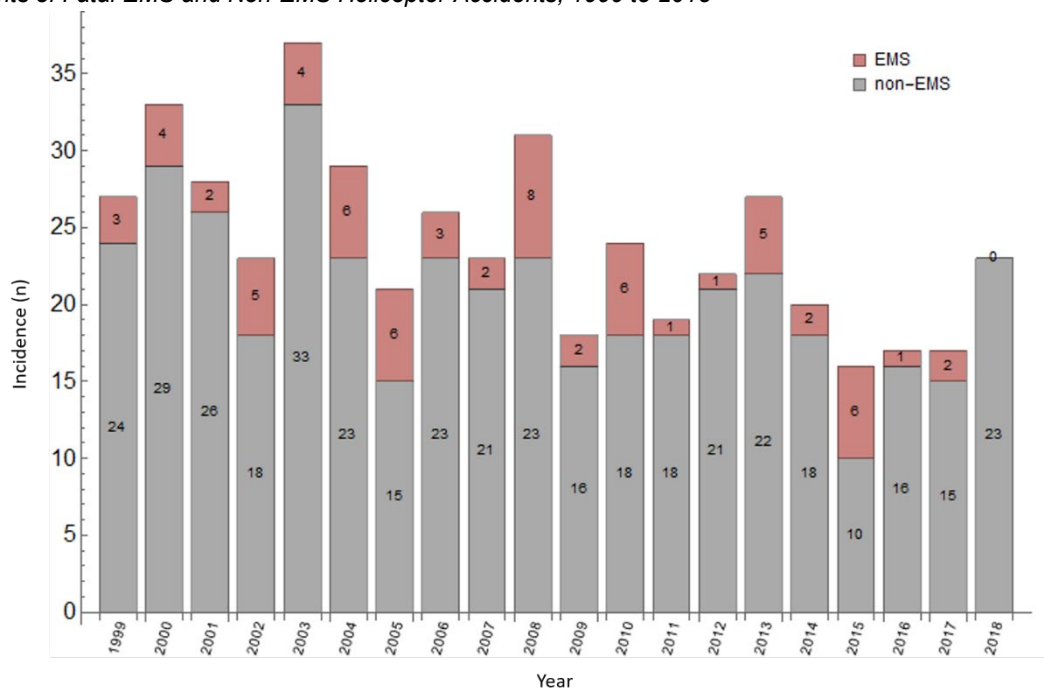


Note. EMS = emergency medical service.

Figures 3 and 4 show that EMS counts for fatal helicopter accidents have also been much lower than those of non-EMS counts (means: 3.5 and 20.6, respectively; 95% CIs: 2.48 to 4.42 and 18.27 to 22.93, respectively). For their linear regression models, the EMS p-value of 0.16 does not reject the null hypothesis of zero slope. However, the non-EMS p-value  $< 0.01$  indicates that the null hypothesis (i.e., the non-EMS linear slope is zero) should be rejected in favor of the alternative hypotheses that the slope is not zero (it is, in fact, negative). Thus, the non-EMS fatal accident count shows a declining trend over the 20-year study period, but the EMS fatal accident count does not.

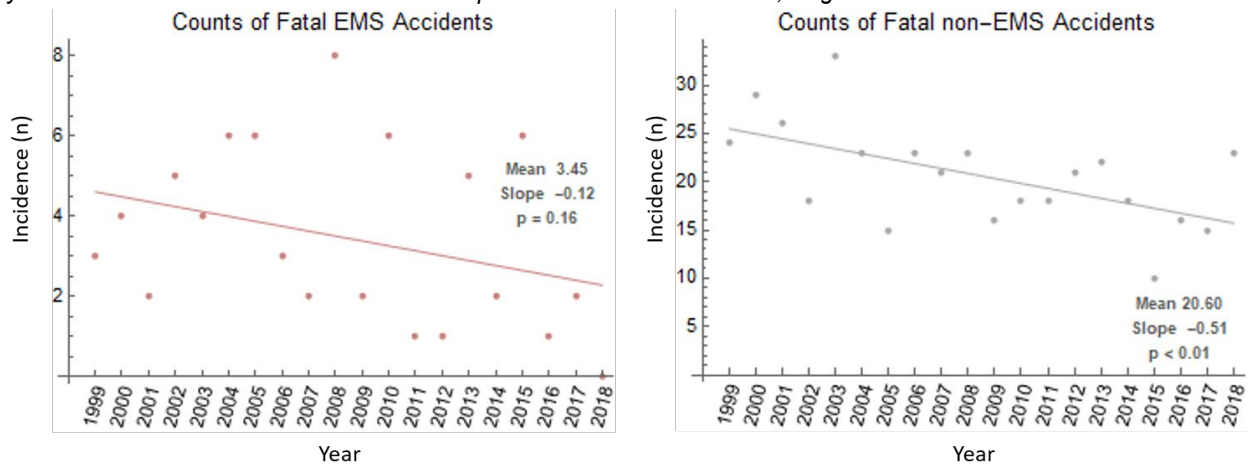


**Figure 3**  
Yearly Counts of Fatal EMS and Non-EMS Helicopter Accidents, 1999 to 2018



Note. EMS = emergency medical service.

**Figure 4**  
Yearly Counts of Fatal EMS and Non-EMS Helicopter Accidents 1999 to 2018, Regression View



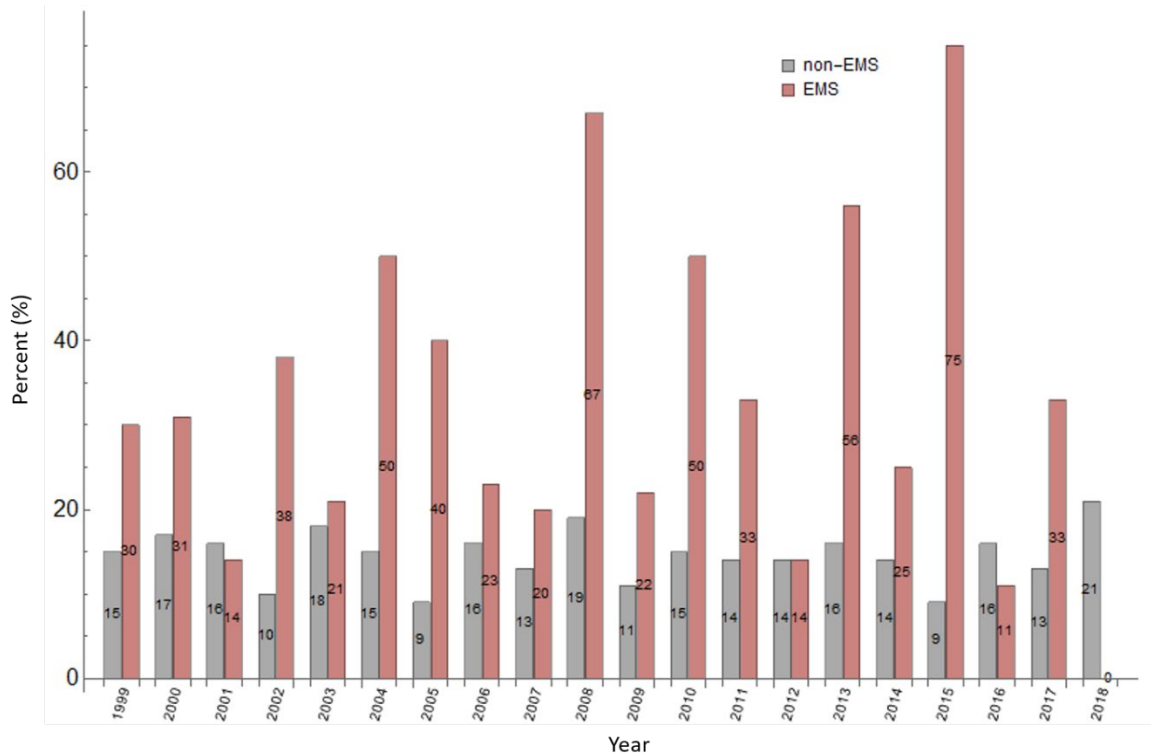
Note. EMS = emergency medical service.

Figures 5 and 6 present the percentage of all fatal accidents. The percentage of EMS accidents that are fatal (mean: 32.65%) is much higher than that of non-EMS accidents (mean: 14.55%). The p-value of a paired Student’s t test comparing the two means is less than 0.01. This indicates that

the null hypothesis (i.e., the means are the same) should be rejected in favor of the alternative that the EMS means differ (the EMS mean is, in fact, higher). In addition, the linear regression models for both EMS and non-EMS fatal percentages with p-values of 0.93 and 0.90, respectively, indicate that the null hypotheses of zero slope (and therefore, no year-to-year change) cannot be rejected for either EMS or non-EMS fatal percentage.

**Figure 5**

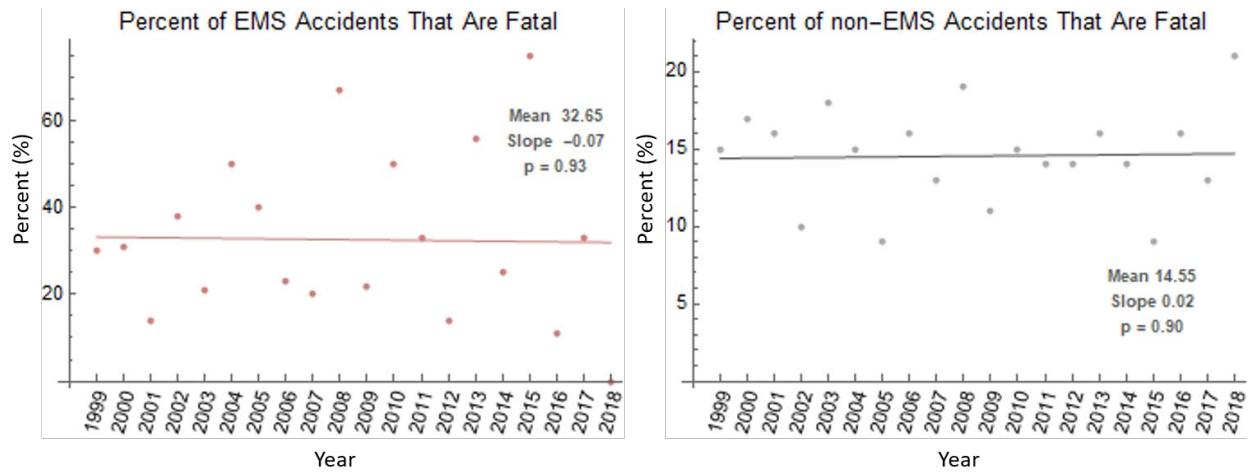
*Fatal Helicopter Accidents as a Percentage of All Helicopter Accidents for EMS and Non-EMS, 1999 to 2018*



Note. EMS = emergency medical service.

**Figure 6**

*Fatal Helicopter Accidents as a Percentage of All Helicopter Accidents for EMS and Non-EMS, 1999 to 2018, Regression View*

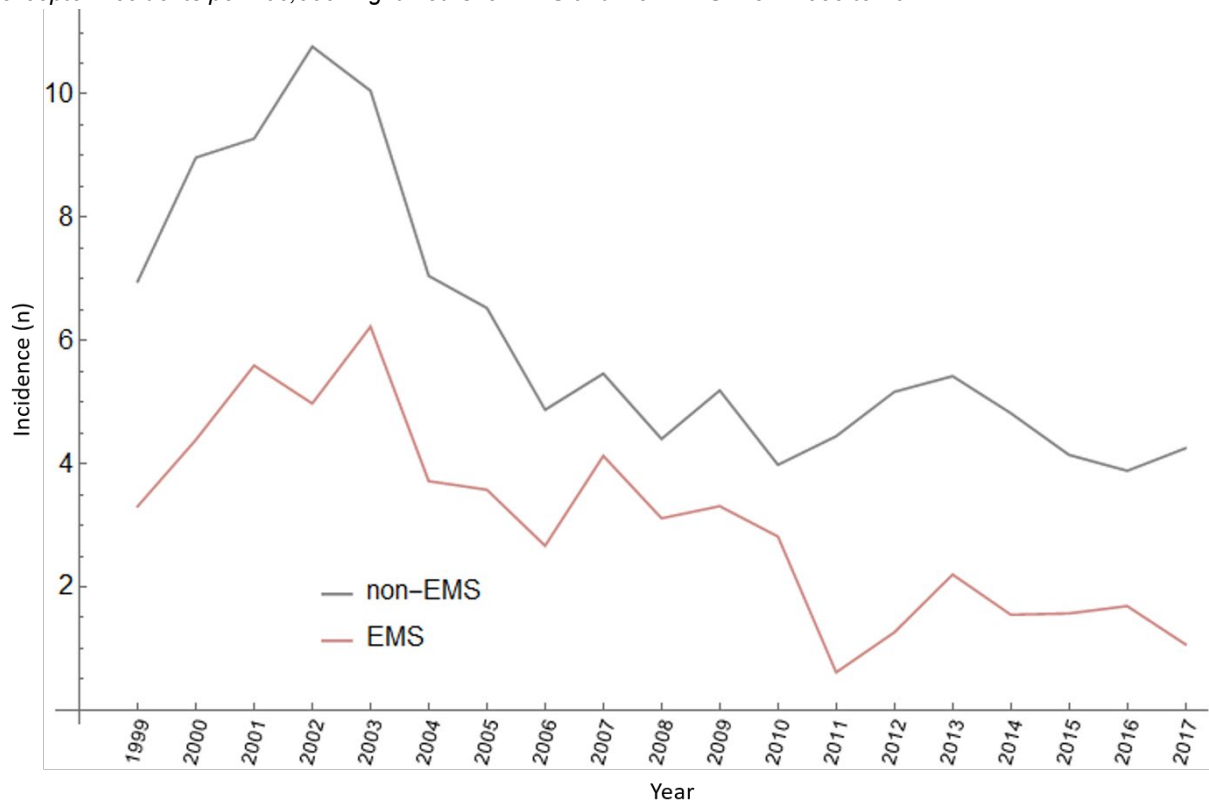


Note. EMS = emergency medical service.

Figures 7 and 8 compare the number of EMS and non-EMS accidents per 100,000 flight hours. A paired Student's t test with a p-value less than 0.01 indicates that a null hypothesis of equal means should be rejected in favor of an alternative that the means differ (the non-EMS mean, 6.09, is greater than EMS mean, 3.04). The linear regression models indicate that both EMS and non-EMS accident rates (per flight hour) have decreased over the study period. The null hypotheses of zero slopes should be rejected since the p-values are both less than 0.01. In addition, the models show that the non-EMS accident rate decreased somewhat more (linear slope -0.31) than the EMS rate (linear slope -0.23) over the study period.

**Figure 7**

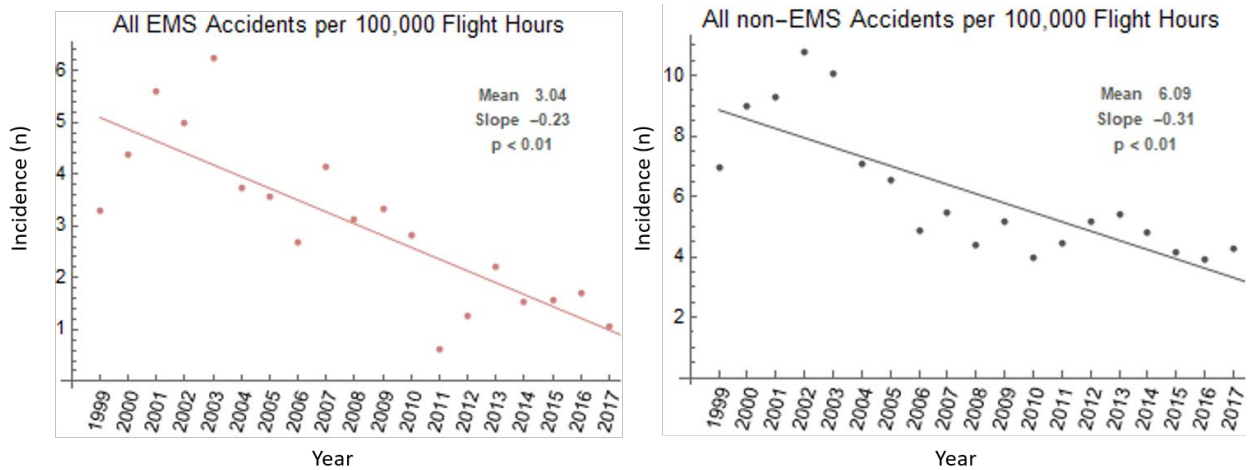
All Helicopter Accidents per 100,000 Flight Hours for EMS and Non-EMS From 1999 to 2017



Note. EMS = emergency medical service.

**Figure 8**

All Helicopter Accidents per 100,000 Flight Hours for EMS and Non-EMS From 1999 to 2017, Regression View

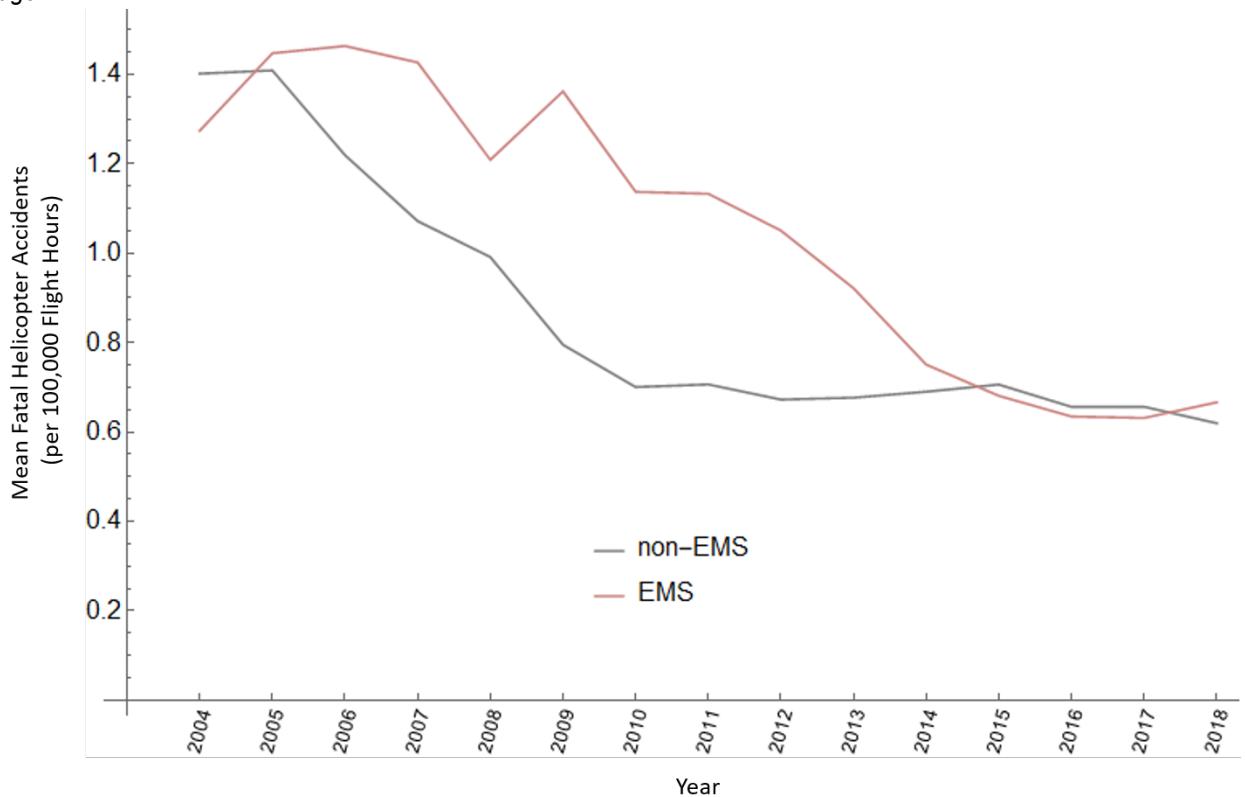


Note. EMS = emergency medical service.

Figures 9 and 10 compare the number of EMS and non-EMS fatal accidents per 100,000 flight hours. A paired Student's t test with p-value of 0.37 indicates that a null hypothesis of equal means should not be rejected. The fatal accident rates did not differ between EMS and non-EMS helicopter flights. The linear regression models indicate that both EMS and non-EMS fatal accident rates (per flight hour) have decreased over the study period. The null hypotheses of zero slopes should be rejected since the p-values are both less than 0.05. In addition, the models show that the EMS and non-EMS fatal accident rates have decreased at approximately the same rate over the study period. The data in Figure 5 are represented as a five-year moving average due to the large year-to-year variation.

**Figure 9**

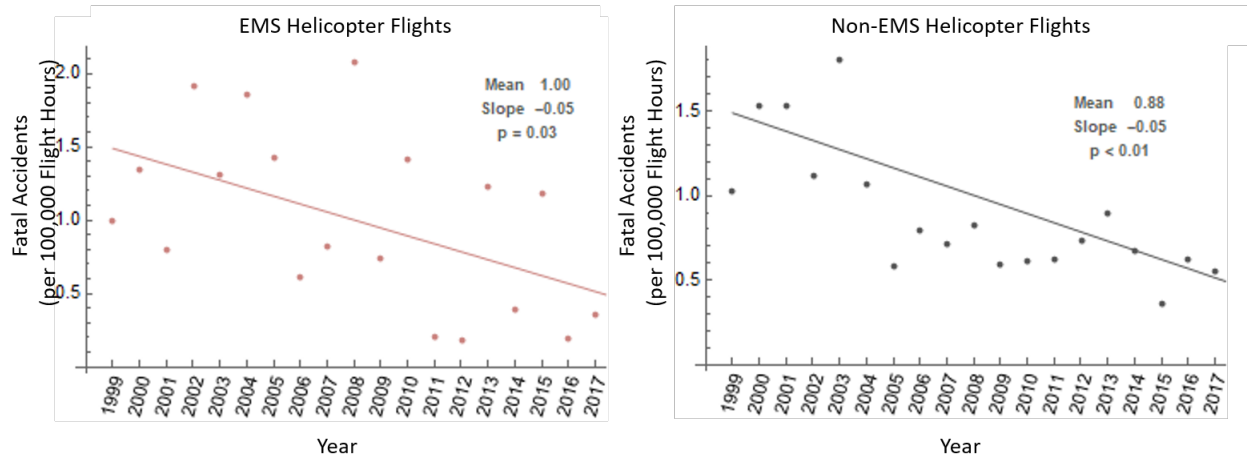
*Fatal Helicopter Accidents per 100,000 Flight Hours for EMS and Non-EMS From 2004 to 2018, Five-Year Moving Average*



Note. EMS = emergency medical service.

**Figure 10**

*Fatal Helicopter Accidents per 100,000 Flight Hours for EMS and Non-EMS From 1999 to 2017, Regression View*

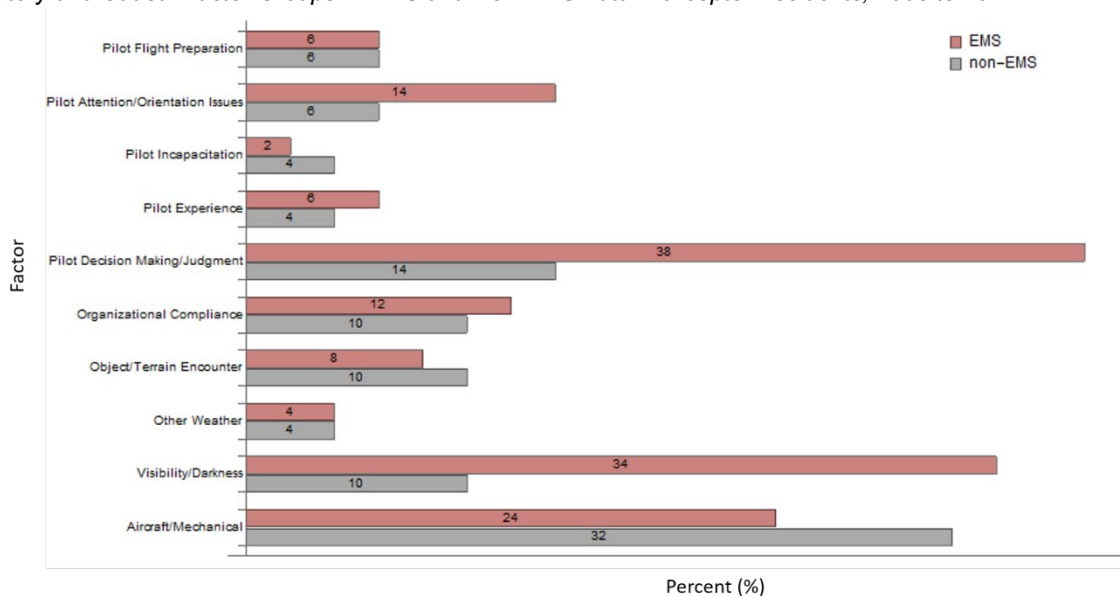


Note. EMS = emergency medical service.

Figure 11 shows the percent of fatal accidents in which each specific factor group included factors cited by NTSB investigators as contributing to or causing the accident. The graph can be used to compare EMS and non-EMS fatal accident factor groups. For each factor group, a chi-square test was performed to test the null hypothesis that the percentage of fatal accidents was the same for EMS and non-EMS. There were three factor groups for which the null hypothesis was rejected: Pilot Attention/Orientation Issues, Pilot Decision Making/Judgement, and Visibility/Darkness. In each case, the EMS accident percentage was much greater than the non-EMS percentage.

**Figure 11**

*Contributory and Causal Factor Groups in EMS and Non-EMS Fatal Helicopter Accidents, 2008 to 2017*



Note. EMS = emergency medical service.

Figure 11 lists the 10 factor groups examined in this paper along with the percent of accidents in each group (EMS or non-EMS) associated with that factor group. Table 1 lists the six conditions examined along with their sources in the NTSB database and their summary values for each category (EMS or non-EMS). These conditions were chosen based on suggestions of possible conditions affecting accident risk according to the literature.

Table 2 summarizes the multivariate logistic regression, Model 1, analysis of all (rather than only fatal) EMS and non-EMS helicopter accidents. It lists the conditions and factors for which the model returned a significant ( $p < 0.05$ ) odds ratio (OR). In this model, the OR is the ratio of the odds of an accident being EMS versus it being non-EMS when the parameter (condition or factor) is present.  $OR > 1$  indicates greater odds of the accident being an EMS accident, and  $OR < 1$  indicates lesser odds. Therefore, for example, the odds are 10.54-times more likely that an accident was an EMS accident when pilot incapacitation was given as a contributing factor by the NTSB. A CI accompanies each OR in Table 2.

**Table 1**  
*Conditions Examined*

Condition	Source	Possible Values	Summary*
Certificate class of pilot	FLIGHT_CREW:med_certf	<b>1<sup>st</sup></b> , 2 <sup>nd</sup>	17%, 13%
Second pilot present	AIRCRAFT:second_pilot	<b>Y</b> , N	3%, 17%
Number of engines	AIRCRAFT:num_eng	0, <b>1</b> , 2, 3, 4	79%, 87%
Frame hours since last inspection	AIRCRAFT:afm_hrs_last	numerical	28.1, 39.2
ELT installed	AIRCRAFT:elt_install	<b>Y</b> , N	100%, 62%
Operator same as owner	AIRCRAFT:oper_same	<b>Y</b> , N	43%, 56%

*Note.* ELT = emergency locator transmitter.

\*Value is based on the possible value that is bolded. The summary value before the comma is for EMS, and the one after is for non-EMS accidents. Percents indicate the percent of accidents in each category (EMS or non-EMS) associated with that condition. The Frame hours since the last inspection summary value is a mean value.

**Table 2**  
*EMS Versus Non-EMS Helicopter All Accident Comparison Based on Conditions/Factors*

Condition/Factor	OR	CI	p
Pilot incapacitation	10.54	(1.20, 92.54)	< 0.05
Pilot experience	7.69	(1.09, 54.16)	< 0.05
Visibility/darkness	5.18	(1.64, 16.33)	< 0.01
Organizational compliance	4.91	(1.12, 21.51)	< 0.05
Nonscheduled operations	4.55	(2.08, 9.89)	< 0.01
Multiengine aircraft	3.76	(1.60, 8.86)	< 0.01
Pilot decision-making/judgment	3.38	(1.21, 9.49)	< 0.05

*Note.* OR = odds ratio; CI = confidence interval.

The higher fatality rates of EMS versus non-EMS helicopter accidents was also a point of concern in this study. While only 14% of non-EMS helicopter accidents resulted in at least one death, this rate was 34% for EMS helicopters. Therefore, to understand factors that make EMS helicopter accidents fatal, a logistic regression model, Model 2, was developed to compare fatal EMS versus non-fatal EMS helicopter accidents. Table 3 gives the results based on Model 2, the



class of pilot medical certificate (second-class versus first-class) was associated with greatly increased odds of the accident being fatal (OR 12.53). Similarly, the presence of a second pilot was associated with reduced odds of fatal events (OR 0.02).

**Table 3**  
*EMS Non-Fatal Versus EMS Fatal Helicopter All Accident Comparison Based on Conditions/Factors*

Condition/Factor	OR	CI	p
Second-class versus first-class certificate	12.53	(2.33, 61.80)	< 0.01
Second pilot present	0.02	(0.00, 1.81)	< 0.05

*Note.* EMS = emergency medical service; OR = odds ratio; CI = confidence interval.

The information in this section provides the basis for accepting or rejecting each of the 10 null hypotheses associated with the alternative hypotheses listed in the Introduction.

- i. The number of EMS (non-EMS) helicopter accidents per year has remained constant.  
 This hypothesis was rejected for both EMS and non-EMS helicopter accidents. Figure 2 summarizes the results of linear regression models for annual EMS and non-EMS accident counts. For both, linear slopes of zero would indicate that these counts remained constant over the 20-year study period. The null hypothesis of zero slope was rejected at the 0.05 level.
- ii. The number of fatal EMS (non-EMS) helicopter accidents per year has remained constant.  
 This hypothesis was rejected for non-EMS helicopter accidents but not for EMS helicopter accidents. Figure 4 summarizes the results of linear regression models for annual EMS and non-EMS accident counts. For both, linear slopes of zero would indicate that these counts remained constant over the 20-year study period. The null hypothesis of zero slope was rejected at the 0.05 level for non-EMS but was not rejected for EMS accidents.
- iii. The ratio of fatal to all EMS (non-EMS) helicopter accidents per year has remained constant, and the EMS and non-EMS ratios are the same.  
 Neither hypothesis that the ratio of fatal to all helicopter accidents has remained constant was rejected. Figure 6 summarizes the results of linear regression models for annual EMS and non-EMS fatal to all accident ratios. For both, linear slopes of zero would indicate that these ratios remained constant over the 20-year study period. The null hypothesis of zero slope was not rejected at the 0.05 level for either EMS or non-EMS accidents.  
 The percentage of EMS helicopter accidents that are fatal (mean: 32.65%) is much higher than that of non-EMS helicopter accidents (mean: 14.55%). The p-value of a

paired Student's t test comparing the two means is less than 0.01. This indicates that the null hypothesis (i.e., the means are the same) should be rejected in favor of the alternative that the EMS mean is higher.

- iv. The number of EMS (non-EMS) helicopter accidents per flight hour has remained constant.

Both hypotheses (for EMS and non-EMS) that the number of helicopter accidents per flight hour has remained constant were rejected. Figure 8 summarizes the results of linear regression models for annual EMS and non-EMS fatal to all accident ratios. For both, linear slopes of zero would indicate that these ratios remained constant over the 20-year study period. The null hypothesis of zero slope was rejected at the 0.05 level for both EMS and non-EMS helicopter accidents. In addition, the models indicate that the non-EMS helicopter accident rate decreased somewhat more than the EMS rate.

- v. The number of fatal EMS (non-EMS) helicopter accidents per flight hour has remained constant.

Both hypotheses (for EMS and non-EMS) that the number of fatal helicopter accidents per flight hour has remained constant were rejected. Figure 10 summarizes the results of linear regression models for annual EMS and non-EMS fatal to all accident ratios. For both, linear slopes of zero would indicate that these ratios remained constant over the 20-year study period. The null hypothesis of zero slope was rejected at the 0.05 level for both EMS and non-EMS fatal helicopter accidents. In addition, the models indicate that the EMS and non-EMS fatal helicopter accident rates decreased by approximately the same amount over time.

- vi. The number of EMS and non-EMS helicopter accidents per flight hour is the same.

The rate of EMS helicopter accidents per flight hour (mean: 3.04) is much lower than that of non-EMS accidents (mean: 6.09). The p-value of a paired Student's t test comparing the two means is less than 0.01. This indicates that the null hypothesis (i.e., the means are the same) should be rejected in favor of the alternative that the EMS mean is lower.

- vii. The number of EMS and non-EMS fatal helicopter accidents per flight hour is the same.

A paired Student's t-test with p-value of 0.37 indicates that a null hypothesis of equal means should not be rejected. The fatal helicopter accident rates per flight hour do not differ between EMS and non-EMS helicopter flights.

- viii. The proportion of each contributing factor identified is the same for fatal EMS and fatal non-EMS helicopter accidents.

Figure 11 along with the chi-square hypothesis tests demonstrate that precisely three of the 10 factors examined were associated with fatal EMS helicopter accidents over fatal non-EMS helicopter accidents to a significant extent. Those three factors were:

- Pilot Attention/Orientation Issues,

- Pilot Decision Making/Judgement, and
- Visibility/Darkness.

ix. The ORs of each condition or factor identified is the same for all EMS and all non-EMS helicopter accidents.

Table 2 shows that the ORs were significantly greater for EMS helicopter accidents over non-EMS accidents for seven factors or conditions (in order of increasing OR):

- Pilot incapacitation,
- Pilot experience,
- Visibility/darkness,
- Organization compliance,
- Nonscheduled operations,
- Two-engine aircraft, and
- Pilot decision-making/judgment.

The two factors—visibility/darkness and pilot decision-making/judgment—appear in both the fatal helicopter accident and all helicopter accident lists.

x. The ORs of each condition or factor identified is the same for EMS fatal and EMS non-fatal helicopter accidents.

Table 2 shows that the ORs were significantly greater for EMS fatal helicopter accidents over EMS non-fatal accidents for two conditions:

- Second-class versus first-class medical certificate and
- Presence of a second pilot.

Table 3 also shows that the ORs were significantly lower for EMS fatal helicopter accidents over EMS non-fatal accidents for only one condition: the presence of a second pilot. However, the odds of an EMS helicopter accident being fatal were increased when the pilot held a second-class medical certificate (rather than a first-class certificate).

## DISCUSSION

While the accident rates for all accidents and fatal accidents for both EMS and non-EMS helicopters have been decreasing in the last 20 years, fatal accidents continue to account for a much higher proportion of EMS helicopter accidents than they do for non-EMS accidents. While EMS accident rates per flight hour have remained consistently below those of non-EMS helicopters, EMS fatal accident rates per flight hour have not. Those rates have been nearly the same as those of non-EMS fatal accidents per flight hour, at least over the past five years.

Several factors and conditions were identified that are more prevalent with EMS than non-EMS when considering either fatal or non-fatal helicopter accidents. However, there were two factors—visibility/darkness and pilot decision making/judgment—that were more prevalent in EMS accidents that determined fatality. In addition, with EMS accidents, two factors were much more highly associated with fatal accidents than non-fatal accidents—the pilot having a second-class medical certificate rather than a first-class and the lack of a second pilot.

This study has exposed a much higher proportion of fatal EMS accidents than non-EMS accidents, along with several factors and conditions that distinguish fatal from non-fatal EMS accidents. This study also found factors that distinguish fatal EMS accidents from non-fatal EMS accidents. However, this study was not intended to explore these differences in-depth. Such questions could be the subject of further research. Detailed analyses focusing on this research could lead to a reduction in fatal EMS accident rates.

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## APPENDIX: GROUPING METHODOLOGY FOR CONTRIBUTING AND CAUSAL FACTORS

The National Transportation Safety Board (NTSB) event reports assign one or more contributing or causal factors to each accident. In these reports, each factor is listed by type as either contributing or causal. The NTSB reports assign each accident to an overall category of contributing or causal factors<sup>4</sup>. They may also assign the accident to a subcategory, section, subsection, and modifier. This paper does not distinguish between the two factor types, and it does not require the use of either subsections or modifiers.

Table 4 lists the five categories, examples (not exhaustive) of subcategories within categories, and examples (not exhaustive) of sections within subcategories within categories.

**Table 4**  
*Examples of NTSB Categorization of Accident Contributing or Causal Factors*

<b>Category</b>	
<b>Code</b>	<b>Description</b>
01	Aircraft
02	Personnel issues
03	Environmental issues
04	Organizational issues
05	Not determined
<b>Category - Subcategory</b>	
<b>Code</b>	<b>Description</b>
02-01	Personnel issues – Physical
02-02	Personnel issues – Psychological
02-03	Personnel issues – Experience
02-04	Personnel issues - Action/decision
02-05	Personnel issues – Miscellaneous
02-06	Personnel issues - Task Performance
03-01	Environmental issues - Operating Environment
03-02	Environmental issues - Physical Environment
03-03	Environmental issues - Conditions/weather/phenomena
03-04	Environmental issues -Task Environment
<b>Category - Subcategory - Section</b>	
<b>Code</b>	<b>Description</b>
02-04-15	Personnel issues - Action/decision - Info processing/decision
03-03-50	Environmental issues - Conditions/weather/phenomena - Ceiling/visibility/precip

*Note.* NTSB = National Transportation Safety Board.

<sup>4</sup> The specific codes are in the Findings table of the NTSB Aviation Accident Database.

Table 5 provides a comprehensive list of the NTSB codes for the accidents examined in this paper and their corresponding factor groups. This table was used to assign each NTSB accident factor to one of the 10 factor groups used in this paper.

**Table 5**

*Factor Group Assignment Based on NTSB Category, Subcategory, and Section Codes*

<b>Factor Group</b>	<b>NTSB Code</b>	<b>Category Description (code)</b>	<b>Subcategory Description (code)</b>		<b>Section Description (code)</b>
Aircraft/Mechanical	01	Aircraft (01)			
	030410	Environmental Issues (03)	Task (04)	Environment	Physical workspace (10)
Visibility/Darkness	030350	Environmental Issues (03)	Conditions/weather (03)		Ceiling/visibility (50)
	030360	Environmental Issues (03)	Conditions/weather (03)		Light conditions/dark (60)
Other Weather	030300	Environmental Issues (03)	Conditions/weather (03)		General (00)
	030310	Environmental Issues (03)	Conditions/weather (03)		Temperature/humidity/pressure (10)
	030320	Environmental Issues (03)	Conditions/weather (03)		Turbulence (20)
	030330	Environmental Issues (03)	Conditions/weather (03)		Convective weather (30)
	030340	Environmental Issues (03)	Conditions/weather (03)		Wind (40)
Object/Terrain Encounter	0302	Environmental Issues (03)	Object/terrain encounter (02)		
Organizational Compliance	0301	Environmental Issues (03)	Operating environment (01)		Radar coverage/airport facilities (40,70)
	04	Organizational issues (04)			
Pilot Decision-Making / Judgment	0204	Personnel issues (02)	Action/decision (04)		Incorrect action (10)
	020630	Personnel issues (02)	Task (06)	performance	Use of equipment/information (30)
	020640	Personnel issues (02)	Task (06)	performance	Workload management (40)
Pilot Experience	0203	Personnel issues (02)	Experience/knowldg (03)		



Pilot Incapacitation	0201	Personnel issues (02)	Physical (01)		Impairment/incapacitation/fitness/alertness/fatigue (00,10,20,30,35)
Pilot Attention/Orientation Issues	0202	Personnel issues (02)	Psychological (02)		Attention/monitoring/orientation (15,20)
	020635	Personnel issues (02)	Task (06)	performance	Lack of communication (35)
	030420	Environmental Issues (03)	Task (04)	Environment	Pressures/demands (20)
Pilot/Flight Preparation	020600	Personnel issues (02)	Task (06)	performance	Pilot general (00)
	020610	Personnel issues (02)	Task (06)	performance	Planning/preparation (10)
	020620	Personnel issues (02)	Task (06)	performance	Maintenance (20)

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Note. NTSB = National Transportation Safety Board.