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Factors Associated with Pilot Fatality in Work-related Aircraft Crashes, Alaska, 1990–1999

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Work-related aircraft crashes are the leading cause of occupational fatality in Alaska, with civilian pilots having the highest fatality rate (410/100,000/year). To identify factors affecting survivability, the authors examined work-related aircraft crashes that occurred in Alaska in the 1990s (1990–1999), comparing crashes with pilot fatalities to crashes in which the pilot survived. Using data from National Transportation Safety Board reports, the authors carried out logistic regression analysis with the following variables: age, flight experience, use of a shoulder restraint, weather conditions (visual flight vs. instrument flight), light conditions (daylight vs. darkness), type of aircraft (airplane vs. helicopter), postcrash fire, crash location (airport vs. elsewhere), and state of residence. In the main-effects model, significant associations were found between fatality and postcrash fire (adjusted odds ratio (AOR) = 6.43, 95% confidence interval (CI): 2.38, 17.37), poor weather (AOR = 4.11, 95% CI: 2.15, 7.87), and non-Alaska resident status (AOR = 2.10, 95% CI: 1.05, 4.20). Protective effects were seen for shoulder restraint use (AOR = 0.40, 95% CI: 0.21, 0.77) and daylight versus darkness (AOR = 0.50, 95% CI: 0.25, 0.99). The finding that state of residence was associated with survivability offers new information on pilot survivability in work-related aircraft crashes in Alaska. These results may be useful in targeting safety interventions for pilots who fly occupationally in Alaska or in similar environments. *Am J Epidemiol* 2001;154: 1037–42.

accidents, occupational; aircraft; aviation; occupational health; transportation

Between 1992 and 1998, 2,139 fatalities from work-related aircraft crashes occurred in the United States (1). A work-related crash is defined as a crash in which someone on board was engaging in a work-related function, either as a passenger or as a crew member, at the time of the crash. During the same time frame, aircraft pilots had the fourth-highest risk of occupational fatality in the United States. Fatalities were found to be more likely to occur in the states of Alaska, California, Texas, Florida, and Washington. However, as Suarez observed, "The extraordinarily high number of fatalities occurring in Alaska is noteworthy" (1, p. 41).

Covering over 586,000 square miles (937,600 km^2), Alaska has more than twice the land area of Texas, and with over 47,000 miles (75,200 km) of coastline, it has more coastline than the remaining 49 US states combined (2). It also has 17 of the 20 highest peaks in the United States, yet only 60 percent of Alaska has radar coverage over 10,000 feet (3,047.6 m) above mean sea level. Radar coverage allows aircraft to be seen and followed on a radar screen by air traffic controllers and allows for flight in low-visibility (poor weather) conditions.

Even though Alaska is very large, it has only 12,200 miles (19,520 km) of public roads—approximately the same mileage as Vermont. Furthermore, 90 percent of Alaska's communities are not connected to a highway system (3). Because of this, commuter and air taxi flights must serve in lieu of a traditional road system, making aircraft essential for transportation of passengers and delivery of goods, services, and mail to outlying communities.

Between 1990 and 1999, aircraft crashes in Alaska caused 106 occupational deaths among workers classified as civilian pilots. This is equivalent to 410 deaths per 100,000 pilots per year—approximately 100 times the mortality rate for US workers as a whole (4). The Alaska pilot fatality rate is higher than the fatality rate for any other occupation in Alaska; the two next-highest occupational fatality rates are logging (150/100,000/year) and commercial fishing (125/100,000/year) (5), and this rate is five times the fatality rate for all US pilots (80/100,000/year) (1).

Controlled flight into terrain (CFIT) has been found to be a leading cause of aircraft fatalities in Alaska. A CFIT crash refers to any collision with land or water in which there was no detectable mechanical or equipment failure, where the pilot was in control of the aircraft but lost situational awareness and flew into terrain. A recent study by Thomas et al. (6) identified CFIT crashes in Alaska as entailing higher

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Abbreviations: CFIT, controlled flight into terrain; FAA, Federal Aviation Administration; NTSB, National Transportation Safety Board.

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risks for pilot and passenger fatality; however, the study did not analyze survival factors. Understanding the survival factors associated with both CFIT and non-CFIT crashes is paramount in discerning the risk factors associated with overall aircraft crash fatality in Alaska.

Li and Baker (7) studied pilot survival in US commuter and air taxi crashes occurring from 1983 to 1988. They identified four key factors associated with pilot fatality: postcrash fire, an off-airport crash location, poor weather, and nonuse of a shoulder restraint. Although this study was significant in identifying factors that impact survivability, it was conducted using 1983–1988 crash data, which may not be representative of trends in more recent crashes. Li and Baker also used a national population, which may not be representative of survival factors that appear to be unique to Alaska's flying environment.

Eckert (8) conducted a national descriptive study of fatal commercial air transport crashes occurring between 1924 and 1981. This study provided historical baseline data on aircraft crashes but provided no analysis of variables associated with pilot survival and provided no data beyond 1981. Eckert included national data for all categories of air transportation, which may not be useful for Alaska-specific air taxi and commuter crashes.

Li and Baker (9) also conducted a national study examining the injury patterns of persons who died in aviation crashes during the 1980s (1980–1990). Their findings indicated that despite a 34 percent reduction in aviation-related fatalities, injury patterns remained constant. These injury patterns demonstrated that blunt injuries resulting from deceleration forces, particularly head injuries, were the most life-threatening to occupants in aviation crashes.

Alaska is widely regarded as having a unique aviation environment for crashes, with different risks than those incurred elsewhere in the United States. Pilot information on necessary flying skills specific to the area is largely passed on by word of mouth or by reading aviation magazines. Articles written on flying in Alaska describe typical conditions as rough terrain, sparse population, and unpredictable weather and emphasize the geographic and climatic impediments to air transportation (10–13). The sheer numbers of commuter and air taxi operations in Alaska, due mostly to the lack of roads, are also seen as being representative of the distinctiveness of the Alaskan flying environment.

In the current study, we sought to determine factors associated with pilot survival in work-related aircraft crashes in Alaska and to determine whether risk factors in Alaska vary from those seen elsewhere in the United States. To accomplish this, we evaluated all work-related aircraft crash fatalities that occurred in Alaska from 1990 through 1999. Through this evaluation, we hoped to find ways to decrease the high pilot fatality rate from occupational aircraft crashes in Alaska.

MATERIALS AND METHODS

To evaluate factors associated with crash survivability, we abstracted data from the Alaska Occupational Injury Surveillance System and from National Transportation Safety Board (NTSB) summaries for air taxi crashes occurring in 1990–1999. The analysis used data abstracted from the NTSB crash reports and entered into a database maintained by the Federal Aviation Administration's (FAA) National Aviation Safety Data Analysis Center. According to the FAA and the NTSB, an aviation "accident," referred to as a "crash" in this report, is "an occurrence associated with the operation of an aircraft which takes place between the time any person boards the aircraft with the intention of flight and until such time as all such persons have disembarked, and in which any person suffers death or serious injury, or in which the aircraft receives substantial damage" (14).

An accurate record of commercial pilots operating in Alaska who were not involved in crashes during this period does not exist. Because of the lack of adequate exposure data for all commercial pilots operating in Alaska (i.e., denominator information), a traditional case-control approach was not feasible. Thus, a comparative analysis of fatal crashes versus nonfatal crashes was completed. Crashes in which the pilot in command died were compared with crashes in which the pilot in command survived. Initial analysis included crude models utilizing Wald χ^2 statistics to test the relations between individual variables and the outcome of interest (pilot fatality). A main-effects logistic regression model was also tested to determine the relation between the dependent and independent variables. Odds ratios were then generated in a final adjusted model. Statistical Analysis System software (SAS Institute, Inc., Cary, North Carolina) was utilized in data analysis.

All variables, except age, were dichotomized for entry into logistic regression models. Dichotomous variables that were evaluated included use of a shoulder restraint (no = 0, yes = 1), meteorologic conditions (visual flight conditions vs. instrument flight conditions—used as a marker for poor weather) (visual = 0, instrument = 1), light conditions (darkness = 0, daylight = 1), type of aircraft (airplane = 0, helicopter = 1), presence of postcrash fire (no = 0, yes = 1), location of crash (on-airport = 1, off-airport = 0), and pilot's state of residence (Alaska = 0, other = 1). Pilot flight experience was dichotomized by determining the median flight experience of all pilots in the study (4,350 hours) and grouping the data according to that figure (greater than median = 1, less than median = 0). Crude models for each risk factor were modeled with pilot fatalities; then a final model incorporating all variables was completed.

RESULTS

During the 1990s, there were 675 work-related aircraft crashes in Alaska. In 567 of these crashes, the pilot survived, and in 108 crashes, the pilot died. Table 1 shows the distribution of data on the variables included in the study.

Crude logistic regression models were completed wherein each variable was modeled with pilot fatality to test for relations. The crude odds ratios shown in table 2 demonstrate that postcrash fire was the strongest predictor of fatality: The estimated odds of dying were 14 times higher when a fire occurred after the crash than when one

TABLE 1. Frequency of assessed risk factors for pilot survival in work-related aircraft crashes, Alaska 1990-1999*

Exposure variable	Fatal crash (*n* = 108)		Nonfatal crash (*n* = 567)	
	No.	%	No.	%
Fire after crash				
Yes	28	25.9	15	2.6
No	77	71.3	552	
Unknown	3		0	
Use of shoulder restraint				
Yes	52	48.1	468	82.5
No	19	17.6	77	13.6
Unknown	37		22	
Weather conditions				
Instrumental meteorologic conditions	37	34.3	45	7.9
Visual meteorologic conditions	66	61.1	522	92.1
Unknown	5		0	
Light conditions				
Daylight	84	77.8	490	86.4
Darkness	23	21.3	77	13.6
Unknown	1		0	
Location of crash				
Off-airport	27	25.0	218	38.4
On-airport	81	75.0	349	61.6
State				
Non-Alaska	20	18.5	67	11.8
Alaska	88	81.5	495	87.3
Unknown	0		5	
Flight experience (hours)				
>4,350	47	43.5	284	50.1
<4,350	60	55.5	277	48.9
Unknown	1		6	
Type of aircraft				
Helicopter	9	8.3	60	10.6
Airplane	99	91.7	507	89.4
Mean age (years)†				
Age	41.4 (10.7)‡		40.7 (10.8)	
Unknown	0		5	

* Totals vary because of missing data.
† Continuous variable.
‡ Numbers in parentheses, standard deviation.

did not. In addition, flights that crashed under instrument weather conditions also had higher estimated odds of pilot death. These crashes were seven times more likely to be fatal than crashes occurring under visual flight conditions. The estimated odds of pilot death were also higher when the crash occurred at an off-airport location. Two variables demonstrated protective relations. The first, light conditions, showed that odds of pilot death were lower for crashes occurring in daylight than for those occurring in darkness. The second protective variable was use of a shoulder restraint. That is, the estimated odds of pilot death were lower when the pilot used a shoulder restraint than when one was not used.

For the full main-effects model that included all variables, the logistic regression procedure deleted all observations with missing data, leading to deletion of 70 observations with missing values on one or more variables. This gave us a final model with 605 observations, 534 nonfatal and 71 fatal. Most missing data came from the variable on shoulder restraint use (59 observations had unknown information), with proportionally more fatal crashes than nonfatal crashes missing this value. An analysis of 37 fatal crashes for which shoulder restraint use could not be determined demonstrated that, in many cases, factors associated with the crash made that determination impossible. For instance, fire consumed the aircraft in 20 crashes; five aircraft were involved in

TABLE 2. Crude and adjusted odds ratios for pilot survival in work-related aircraft crashes, according to pilot-survival exposure variables, Alaska, 1990-1999

Exposure variable	Crude OR‡	95% CI‡	Adjusted OR	95% CI
Fire after crash				
Yes	13.78*	6.84, 26.16	6.43*	2.38, 17.37
No	1.0		1.0	
Weather conditions				
Instrumental meteorologic conditions	6.78*	4.10, 11.22	4.11*	2.15, 7.87
Visual meteorologic conditions	1.0		1.0	
Location of crash				
Off-airport	1.87*	1.17, 2.99	3.01*	1.50, 6.01
On-airport	1.0		1.0	
Light conditions				
Daylight	0.57*	0.34, 0.97	0.50*	0.25, 0.99
Darkness	1.0		1.0	
Use of shoulder restraint				
Yes	0.45*	0.25, 0.80	0.40*	0.21, 0.77
No	1.0		1.0	
State				
Non-Alaska	1.68†	0.97, 2.91	2.10*	1.05, 4.20
Alaska	1.0		1.0	
Flight experience (hours)				
>4,350	0.76	0.5, 1.16	0.56	0.30, 1.05
<4,350	1.0		1.0	
Type of aircraft				
Helicopter	0.77	0.37, 1.60	0.86	0.37, 2.0
Airplane	1.0		1.0	
Mean age (years)§	1.01	0.99, 1.03	1.01	0.98, 1.04

* $p < 0.05$ (Wald χ^2 test).
† $p = 0.07$ (Wald χ^2 test).
‡ OR, odds ratio; CI, confidence interval.
§ Continuous variable.

CFIT crashes that completely destroyed the aircraft; four aircraft sank in water and were not recoverable; three aircraft could not be found; and five were missing for unknown reasons.

After all of the variables were introduced into the model, most relations remained consistent with those of the crude models. However, pilot's state of residence achieved statistical significance when it was included with the other variables. These results are summarized in table 2. In crashes where the pilot was not an Alaska resident, the odds of fatality were twice as high as when the pilot was an Alaska resident. This relation may be dependent upon the combined effects of the other variables, which may explain why it was not significant in the crude model.

We tested a main-effects model excluding the shoulder restraint variable to determine whether the high level of missing information on this variable substantially changed the results. In this model, fire, instrument weather conditions, and off-airport location remained significant risk factors for fatality, and daylight remained a significant protective factor. However, non-Alaska residence dropped out as a significant risk factor for fatality, while increased flight experience demonstrated a significant relation with survival.

DISCUSSION

The results of this study on aircraft crash fatalities in Alaska appeared similar to results seen nationally, with post-crash fire, an off-airport crash location, and instrument flight conditions having a significant association with fatality and use of a shoulder restraint and daylight having a significant association with survival (7). The similarity between results suggests that interventions designed to decrease crashes that have worked in other areas may also be successful in Alaska. However, this study showed a significant relation for survival if the pilot was an Alaska resident. One possible explanation for this effect would be that as a pilot gains flight experience in Alaska, chances for a safer landing or the performance of emergency actions are improved. These results offer new information on factors associated with pilot survivability in work-related crashes occurring in Alaska.

Postcrash fire was the strongest predictor of fatality for pilots in this study. Pilots in these types of crashes might benefit from fire-resistant clothing that gives them more time to exit a burning aircraft. In many cases, a pilot is aware that impact is imminent and can take measures that increase survivability, such as assuming a braced position and/or lessening the angle of impact. In addition, fuel systems that could withstand impact forces more effectively and keep from igniting when a crash occurred could lessen the number of postcrash fires, improving survivability.

Flying under instrument conditions was also highly associated with fatality. Few aircraft and facilities allowing for instrument navigation exist in Alaska. Company policies that encourage pilots to return to base if they encounter conditions requiring instrument navigation or that discourage pilots from taking off in marginal weather may aid in decreasing pilot fatality. Additional training of pilots in the use of emergency procedures that should be implemented if instrument conditions are unexpectedly encountered might also decrease this rate.

The high level of missing data for fatal crashes in which shoulder restraint use was unknown was probably due to the severity of those crashes. Some of these crashes were not survivable, while others may have incapacitated the pilot only temporarily. Nevertheless, temporary incapacitation might keep a pilot from exiting the aircraft prior to a fire's breaking out and smoke's consuming the aircraft, causing death. Crash severity often precluded determination of shoulder restraint use because the restraint had been burned away or the aircraft had been destroyed so completely that there was not enough evidence to determine use. In some of these cases, the use of a shoulder restraint would not have affected survival. In the main-effects model excluding shoulder restraint use, the strong relations maintained for fire, weather, location, and light conditions suggest that the missing data had little effect on the results. However, the changing relations for state of residence and flight experience require further investigation.

In an NTSB study of crashes of noncommercial small aircraft occurring between 1972 and 1981, it was shown that most crashes involved circumstances where the crash forces themselves were survivable—that is, within human tolerance—with aircraft cabin areas remaining substantially intact. After studying impact angles, air speeds, and the tolerance of the human body to impact, the NTSB concluded that installation and use of shoulder restraints would provide a 20 percent reduction in fatality and reduce the severity of injury for 88 percent of the seriously injured occupants (15).

Many older aircraft are not equipped with shoulder restraints (15). In 1977, the FAA mandated installation of shoulder restraints in the crew positions of all small aircraft manufactured after July 1978. Thus, any small aircraft manufactured prior to July 1978 would require after-manufacture retrofitting performed by the owner/operator on a voluntary basis. This regulation was supplemented in 1986 to require that all seats in newly produced small aircraft (not just crew seats) be equipped with lap belts and shoulder restraints. Modifications needed in order to retrofit these older aircraft with restraints are relatively inexpensive, costing $800–$2,000, on average, depending on the amount of structural reinforcement needed (Dr. Jon Bolles, National Institute for Occupational Safety and Health, personal communication, 2001). Retrofitting commercially used aircraft with shoulder restraints might improve survivability.

Currently, the FAA does not require shoulder restraints to be worn in flight, only for takeoff and landing (14). For crashes in which the initial impact is survivable, having the shoulder restraint fastened could improve outcomes and decrease temporary incapacitation from crash injuries. Therefore, requiring use of a shoulder restraint throughout the flight should be considered as a possible additional measure for reducing fatalities.

The National Institute for Occupational Safety and Health recently undertook a joint initiative with the FAA, the NTSB, and the National Weather Service to reduce work-related aviation injuries and fatalities. To accomplish this, officials will complete detailed analyses of crash data, collaborate with aircraft operators, evaluate new technologies, and obtain an accurate and reliable source of denominator data for pilots operating in Alaska. Combined with results from this study and future work, this information will be useful in implementing interventions aimed at decreasing the number of work-related aircraft crashes and increasing survivability for pilots involved in such crashes.

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