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Epidemiology of Work-Related Aviation Fatalities in Alaska, 1990–94

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Alaska, with less than one-half of 1% of the United States workforce, accounts for 9% of all occupational aviation fatalities nationally; 30% of all occupational fatalities in Alaska are related to aviation. To understand this high mortality, we investigated occupational aviation crashes to identify risk factors. Occupational aviation fatalities in Alaska during 1990–94 were examined using National Transportation Safety Board reports and merged with records from the Alaska Occupational Injury Surveillance System. There were 876 aircraft crashes; 407 (46%) were work-related. Occupational crashes were 2.2 times (CI: 1.5, 3.2) more likely to result in fatalities than non-occupational crashes. Risk factors identified included poor weather conditions defined as Instrument Meteorological Conditions (IMC). A crash during IMC was 5.3 times (CI: 3.5, 7.9) more likely to result in fatalities than crashes in other conditions. Of aircraft involved in fatal occupational incidents, 33% were not completely destroyed, allowing the potential for survivors. An estimated 30% reduction in fatalities could have occurred if current technology in occupant protection had been used.

AVIATION IN ALASKA operates in a unique environment found nowhere else in the United States. Alaska is twice the size of Texas, encompassing more than 1.5 million km^2. Vast mountain ranges and glacial ice are barriers to both road and rail transportation, resulting in only 29,000 km of paved roadway (22). Added to this unique environment is a small (n = 553,127), widely dispersed population resulting in a population density of less than one person per square mile, less than one-forth the population density of Wyoming, the next least populated state (7).

Aviation plays a major role in the transportation of equipment and persons engaged in all types of occupational activities throughout Alaska. Alaskan workers have a higher exposure to all types of aircraft when compared with others in the United States. Alaska has 6 times as many pilots, 14 times as many aircraft, and 76 times as many commuter airline flights per capita when compared with the rest of the U.S. (15).

Occupational aviation is not without risk, nor is it a realistic assumption that risk-free flying is attainable due to the large variations in Alaska's geography, climate, and special air transportation needs. However, understanding the risks and applying this knowledge could reduce the hazards of flying in Alaska.

METHODS

To characterize occupational aviation mortality in Alaska we gathered information from multiple sources. For all aircraft crashes in Alaska during the study period (1990–94), National Transportation Safety Board (NTSB) Preliminary (18) and Brief of Accident (16) reports were abstracted to obtain information about flight purpose, weather, aircraft, pilot, and probable cause. These reports were merged with records from the Alaska Occupational Injury Surveillance System (3), a database established and maintained by CDC's National Institute for Occupational Safety and Health, which includes information about cause of death, occupation of decedent, and circumstances associated with the crash. This study includes all occupational deaths related to commercial, military, and general aviation.

For this analysis, an aircraft crash was defined as an incident in Alaska in which an aircraft in motion sustained substantial damage or an incident that resulted in injury or death to an aircraft occupant. An aircraft crash was categorized as occupational if at least one of the occupants in the aircraft was: 1) working for pay or compensation; 2) working as a volunteer emergency medical technician, firefighters, or law enforcement officer; 3) traveling on business, including to and from customer/business contacts; or 4) engaging in a work activity in which the aircraft is the work environment (11). Denominator data for occupational death rates were based on 1990 U.S. Bureau of the Census data (7) and workforce estimates from the Alaska Department of Labor.

RESULTS

During the 5-yr study period there were 876 aircraft crashes; 46% (n = 405) were work related. Overall, 106 (12%) of all crashes resulted in at least one fatality. Stratification of fatal aircraft crashes in Alaska into occupational and non-occupational flights demonstrated that

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TABLE I. FATAL OCCUPATIONAL VS. FATAL NON-OCCUPATIONAL AIRCRAFT CRASHES.

Flight Type	Total Crashes	Fatal Crashes	Rate Ratio (95% CI)
Occupational Flight	405	69 (17%)	2.2 (1.5–3.2)
Non-Occupational Flight	471	37 (8%)	

The percentage shown in the Fatal Crash column is the number of crashes resulting in a fatality divided by the number of Total Crashes. The confidence interval (CI 95%) is the computed interval with a given probability, e.g., 95%, that the true rate is contained within the interval.

occupational crashes were 2.2 times (95% CI: 1.5, 3.2) more likely to result in fatalities when compared with non-occupational aircraft crashes (**Table I**) and significantly ($\chi^2 = 9.3$, $p = 0.002$) more likely to kill or injure a greater proportion of individuals onboard the aircraft in the event of a crash. Overall, 69 (17%) of all occupational aircraft crashes (n = 405) resulted in fatalities, whereas only 37 (8%) of non-occupational aircraft crashes (n = 471) resulted in fatalities. During the study period, the occupational death rate for pilots in Alaska was 268/100,000/yr, 2.1 times higher than the U.S. rate of 126/100,000/yr. For all workers in Alaska, regardless of their occupation, the death rate for work-related aircraft crashes was 8.3/100,000/yr, 27.1 times higher than the U.S. rate of 0.3/100,000/yr (12).

Of the 69 fatal occupational aviation crashes during the study period, 62 (90%) occurred in fixed-wing aircraft and 7 (10%) in helicopters. Nearly all (61 [98%]) of the fixed-wing crashes occurred in propeller type aircraft; 54 (89%) were single-engine aircraft. There were no significant differences between occupational and non-occupational fatal crashes in aircraft type (single vs. multi-engine) or the proportion of aircraft completely destroyed during a crash. No occupational fatalities occurred on scheduled commercial airline operations.

There were 192 occupants aboard the fatal occupational aviation aircraft, both occupational and non-occupational; 149 of those received fatal injuries, a survival rate of only 22%; of the fatal injuries, 99 (70%) were occupational. The mean number of persons onboard the aircraft was 2.8 (range 1–11); 23 (33%) of the fatal aircraft crashes had only the pilot onboard at the time of the crash. The mean age of the victims was 39, ranging from 20–68 yr of age. Persons age 30–44 accounted for 58 (59%) of the total number killed. Women accounted for only 3 (3%) of the occupational aviation fatalities in Alaska during the study period.

Fatal occupational injuries occurred to 37 pilots, 12 hunting/fishing guides, 11 military personnel, 6 miners, 6 loggers, 4 biologists, and 23 other workers from a variety of occupations that were being transported by air (Table II). The number of pilots may appear to be low; however, often the individual piloting the aircraft was classified in another occupational category such as a guide or engineer as this was their primary occupation and piloting an aircraft was incidental to their business or employment activity.

An examination of medical examiner and autopsy reports found that the most common cause of death of aircraft occupants was multiple impact injuries, followed by head injuries, and injuries to the chest (Table III).

TABLE II. OCCUPATIONAL FATALITIES BY EMPLOYMENT TYPE.

Occupation	Number
Pilots	37
Guides	12
Military	11
Miners	6
Loggers	6
Biologist	4
Administration	4
Fishers	3
Engineers	3
Clergy	3
Geologist	2
Teacher	2
Other	6
Total	99

Note: Occupational Category other than Pilots may have been flying the aircraft.

The summer months (June–September) accounted for 36 (52%) of the fatal occupational aviation crashes. August (13, [19%]) was the most frequently cited month and January (1, [1%]) the least. Alaska's northern latitude cause the hours of daylight to vary to a greater extent than elsewhere in the United States. Therefore, we calculated the daylight status at the time of each fatal occupational aviation crash. Most (58, [84%]) of the fatal crashes occurred during daylight hours. The hours between 8:00 a.m. and 7:59 p.m. accounted for 54 (78%) of the fatal occupational crashes.

The takeoff and landing phases of flight together accounted for 228 (56%) occupational crashes, but for only 11 (16%) of the fatal occupational crashes. Most (137 [60%]) of these crashes were associated with unimproved, off-airport sites (e.g., sandbars, mountain ridges, and meadows).

Controlled flight into terrain during the cruise phase of flight (i.e., straight and level flying) or the maneuvering phase of flight (i.e., changing altitude or direction) together accounted for 44 (64%) fatal occupational crashes (Table IV). The most common (28 [41%]) impact sites of fatal crashes were mountain sides and passes, followed by flat land and valleys (16, [24%]), and water (13, [19%]).

TABLE III. OCCUPATIONAL FATALITIES BY CAUSE OF DEATH.

Cause	Number
Multiple Impact Injuries	48
Head Injury	27
Chest Injuries	11
Spinal Cord Injuries	3
Blunt Force Trauma	2
Carbon Monoxide	2
Drowning	2
Hypothermia	2
Myocardial Infarction	2
Total	99

TABLE IV. FATAL OCCUPATIONAL CRASH, PHASE OF FLIGHT.

Phase of Flight	Number
Cruise	23
Maneuvering	21
Landing	6
Takeoff	5
Climb	4
Approach	3
Decent	1
Standing	1
Hover	1
Total	65

Note: Removed Unknown (n = 4).

To investigate impact location further, we stratified by license type the pilot held before the crash. In order of increasing training and experience the categories were Private Pilot, Commercial Pilot, and Airline Transport Pilot. We found no statistical relationship between impact location and license type.

Precipitation (i.e., rain, snow, sleet, or a mixture thereof) was reported in 22 (32%) of all fatal crashes. Perhaps even more revealing is the reported meteorological condition at the crash site: 29 (53%) of all fatal crashes occurred when visibility was poor, defined as Instrument Meteorological Conditions (IMC). Stratification by license type showed that Commercial Pilots were 1.4 times more likely and Airline Transport Pilots were 2.3 times ($\chi^2 = 3.7$, $p < 0.05$) more likely to have IMC present if they were involved in a fatal crash when compared with pilots holding only a Private Pilots license. An occupational crash in IMC was 5.3 times (95% CI: 3.5, 7.9) more likely to result in a fatality than crashes in other weather conditions (Table V).

Of the 29 crashes that occurred in IMC conditions, only one pilot had filed an Instrument Flight Rule flight plan with the FAA. Overall, 24 (35%) of all fatal crashes did not have any flight plan in effect at the time of the crash. Flight Plan use increased for Commercial and Airline Transport Pilots when compared with Private Pilots ($\chi^2 = 9.4$, $p < 0.05$).

Pilot error was determined by the NTSB to have been a contributing cause in 53 (77%) of the fatal occupational aviation crashes in Alaska; this proportion of pilot error was comparable with the rest of the United States (4). Stratification by license class showed no statistical difference between license types and pilot error.

DISCUSSION

In the United States, air transportation is the seventh leading cause of fatal occupational injury, killing approximately 220 workers annually (6). In Alaska however, air transportation related fatalities were second only to water transportation deaths occurring in the fishing industry. Alaska has less than one-half of 1% of the United States workforce, but accounts for 9% of all occupational fatalities related to aviation. A limitation of this study is that the results may underestimate the true number of occupational aviation crashes and fatalities. NTSB reports are not designed nor intended to identify occupational aviation crashes. When possible, multiple data sources were used to overcome this problem (i.e., local state and federal jurisdictional reports, death certificates, and Alaska Department of Labor reports).

The Federal Aviation Administration (FAA) requires pilots who fly for compensation to hold Commercial or Airline Transport Pilot certification (2); advanced training and additional experience are necessary to obtain such certification (Private Pilots may also engage in occupationally-related aviation activities if the flight is incidental to a business-related activity, provided they are not remunerated for pilot duties). With this enhanced training, professional pilots should be better equipped to assess in-flight weather and have better decision-making skills in factors affecting flight safety. However, evidence of poor pilot decision-making skills is frequently cited in NTSB accident records (4).

In Alaska, most occupational aviation activities rely on small, single engine aircraft, as many village and remote airstrips throughout the state are short and constructed from dirt or gravel, making them unsuitable for larger multi-engine aircraft. Current FAA regulations contained in 14 CFR part 135 limit many of the occupational-use airplanes in Alaska (single-engine airplanes) from flying under Instrument Flight Rules (IFR), even if the pilot is qualified to fly in IMC. Consequently, occupational Visual Flight Rule (VFR) flights into IMC demonstrate poor pilot decision-making, whether in initiating the flight or continuing into adverse weather (19). The FAA is currently amending the conditions and limitations to passenger-carrying operations during IMC in single-engine aircraft. The rule will expand the passenger-carrying provisions of the current rule, add equipment and maintenance requirements, and remove the limitations prohibiting single-engine flight in IMC operations. It is unknown what effect, if any, these changes will have on the occupational aviation death rate in Alaska.

Other factors also affect some pilots' decision-making skills. The demand for reliable air service in Alaska places pressure on pilots engaged in occupational aviation. The pressures to perform are at times enormous, and pilots are rarely praised for staying on the ground (13,15). In a recent survey completed by the NTSB, 70% of the pilots involved in the commuter airline and airtaxi industry reported inherent pressures in their flight operations. Self-induced pressure (e.g., job security or monetary concerns) was the most frequently reported source

TABLE V. METEOROLOGICAL CONDITIONS AT CRASH SITE.

Condition	Total Crashes	Fatal Crashes	Rate Ratio (95% CI)
Instrument Meteorological Conditions (IMC)	55	29 (53%)	5.3 (3.5–7.9)
Visual Flight Rules (VFR)	341	35 (10%)	

The percentage shown in the Fatal Crash column is the number of crashes resulting in a fatality divided by the number of Total Crashes. The confidence interval (CI 95%) is the computed interval with a given probability e.g., 95%, that the rate is contained within the interval. Note: Removed Unknown (n = 9).

of pressure, followed by other pilots, passengers, and management (15). In response to this pressure, 50% of the pilots surveyed reported they had intentionally flown from VFR into IMC on at least one occasion and 84% reported that they had inadvertently entered IMC on a VFR flight. The frequency of self-reported VFR flights in IMC suggests that inadvertent or intentional operation of VFR flights in IMC may be accepted as a norm and that VFR flights into IMC are not unique events (20).

Overall, the evidence presented appears to show that advanced certification may not have given pilots better decision-making skills and might have instilled a false sense of security. An alternative explanation of why pilots in Alaska with advanced certification have an increased rate of fatal crashes when compared with private pilots is that they may have an increased exposure to adverse weather conditions and other high risk flying conditions. In either case, these results suggest a need to develop specific training programs that will help professional pilots in Alaska realistically appraise their risks of having a crash.

A limitation of this study is that we were unable to obtain accurate and reliable denominator data to control for exposure (i.e., flight hours). Fatal aircraft accident rates provided by the NTSB are generally stated as fatal accidents per 100,000 aircraft flight hours (24); however, these rates are based upon estimates nationally and extending these estimates to occupational aviation in Alaska is not feasible.

Due to Alaska's high number of aviation incidents, rugged topography, and rapidly changing weather conditions, pilots should be encouraged to consistently obtain a pre-flight briefing and file a flight plan prior to all cross-country flights. Currently, the FAA "strongly recommends" that a flight plan be filed for all VFR flights with the local Flight Service Station (10). Although filing a flight plan would not guarantee proper pre-flight assessment of weather, it would increase the likelihood of pilots being informed of adverse weather conditions in the area in which they plan to operate and help search-and-rescue operations if a crash were to occur. Employers contracting aviation services should assure that filing flight plans is a requirement in their contracts.

Beyond increased training and pre-flight preparation, other measures that may help decrease the number of occupational aviation fatalities should be considered. During the study period, 23 (33%) of the aircraft involved in fatal occupational incidents were not completely destroyed, allowing the potential for survivors; however, only 22% of the people onboard these aircraft survived. Improved aircraft design and the use of personal protective equipment (PPE) can increase the probability of surviving an aircraft crash.

NTSB research suggests that in potentially survivable aircraft crashes (i.e., aircraft not completely destroyed), shoulder harness use could reduce fatalities by 75% (17). If shoulder harnesses had been in use on all occupational flights in Alaska, up to 32 additional Alaskan workers lives could have been saved during the study period. In aircraft manufactured after 1978, shoulder harnesses have been required equipment for all front seat positions and required on all seats in aircraft manufactured after 1987. However, only 14% (n = 1218) of all registered aircraft in Alaska were manufactured after 1978 (5), and shoulder harnesses continue to be rare in older aircraft. Retrofitting older aircraft and extending the availability of shoulder harnesses to seat positions other than the front positions should be considered as possible ways to reduce the number of occupational aviation deaths. However, restraints are only as strong as the object to which they are attached, and often cannot simply be added to the seat. Thus, more substantial modification of the aircraft may be required.

Another strategy to improve aircraft occupant safety is the use of energy-absorbing seats. The human body can tolerate up to 20 g without injury if properly restrained; loads as high as 45 g have been survived, without serious injury, by Air Force volunteers in a series of tests in the 1950's (9). In theory, a person could survive a forward deceleration from approximately 240 $km \cdot h^{-1}$ to a complete stop in one-quarter of a second if they were properly restrained. Most aircraft seats currently in use are not this strong, nor do they incorporate energy-absorbing technology. The standard seat in most (i.e., older) small aircraft currently in use in Alaska is required to withstand only 9 g (1) of forward deceleration before seat failure can be expected, much less than the human body's tolerance. Seats are available that can attenuate the impact forces generated in an aircraft crash, and newer aircraft are required to use these seats. These seats can also withstand greater g forces before a catastrophic seat failure. Use of these seats could reduce occupational aviation-related fatalities.

Given that head injuries were the second leading cause of death during the study period, increasing helmet use by issuing them as personal protective equipment could reduce the number of fatalities. Flight helmets not only attenuate impact forces but can have the added benefit of incorporating hearing protection as well.

Many aircraft in use in Alaska have deficiencies in cockpit and interior space design. For example, a compass mounted on the instrument panel is a lethal target for an occupant's head, in the event of a crash. Small open-ended control wheels offer almost no protection in the event of a crash; many have instruments mounted in the center of the control with protruding knobs. Control panels offer little, if any, protection for head impacts—another reason for helmet use. The lower portions of most small aircraft control panels offer no protection to prevent injuries due to flailing lower limbs during the rapid decelerations and other forces generated during a crash. Attention must be given to the details inside the aircraft if fatalities are to be prevented. Automobile manufacturers have made improvements in interior space by padding the dashboard and other surfaces that occupants may strike during a crash. Airbags and other passive restraint systems are now required in all new U.S. automobiles and impact protection for the driver from the steering control system (i.e., collapsible steering columns) is required (23). The design standards for aircraft seats, occupant restraint systems, and interior protection in most existing Alaskan aircraft are far below those for the family automobile.

CONCLUSION

During the study period, adverse weather conditions were the most frequently identified risk factor in fatal occupational aviation crashes. The Alaskan aviation community is widely aware of this, and both government agencies and Alaskan pilots continue to assert that the weather reporting network in Alaska provides inadequate coverage for aviation activities under VFR (14). Through developing technologies (i.e., global positioning systems, augmented automated surface weather observing systems, and improved communication systems) aviation safety in Alaska may be improved. However, until these technologies can be evaluated and certified by the FAA, the safety record of Alaska aviation could be improved through Alaska-specific pilot training emphasizing weather recognition and mountain flying. The Alaska Aviation Safety Foundation has stated that "the safety record of Alaskan aviation can be improved by greater emphasis on public education, directed at improving pilot skills and emphasis on more realistic risk evaluation (14)." The FAA also supports aeronautical decision-making and judgment training (21).

Beyond the prevention of occupational aircraft crashes through increased training, attention must be given to occupant protection. Insufficient occupant restraint systems and inadequate crashworthiness designs of cockpit and cabin interiors have resulted in excess injury and death (17). As early as 1964 the Civil Aeronautics Board, Bureau of Safety* recommended that the FAA require the use of shoulder harnesses and crash helmets on "low and slow" flights such as wildlife counting and other occupational activities. Personal protective equipment such as shoulder harnesses, helmets, and stronger energy-absorbing seats have been recommended by the NTSB and used by the Department of Defense as effective measures in reducing aviation fatalities (8,17,25).

Reducing the high number of occupational aviation fatalities in Alaska is possible. Fatal aircraft crashes are seldom the result of a single catastrophic event and typically result from a complex chain of events. Often, the links of the chain interact with each other, producing disastrous results. Pilot action or inaction, weather or mechanical problems, and unfamiliar terrain, which on their own would not have caused problems, may suddenly have large consequences. At the moment of impact, new variables enter the causal chain; these determine whether the crash will be fatal. Factors such as aircraft speed, angle of impact, and occupant protection all interact with each other; often the determinants between life and death in these events are small. To break the links in the causal chain and reduce the high number of occupational aviation fatalities in Alaska, various strategies need to be implemented at both the human and aircraft level.

Aviation is expensive and costs associated with retrofitting aircraft to improve safety are considered by many to be a waste of resources. However, the costs of aircraft upgrades and personal protective equipment are small when compared with the overall cost of purchasing and properly maintaining an aircraft, let alone the human costs of an occupational fatality. Aviation is vital to the transportation of workers and equipment in Alaska. Worker safety is the key to ensure the success of this important endeavor.

* The Civil Aeronautics Board, Bureau of Safety, was the forerunner of the National Transportation Safety Board.

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DISCLAIMER: The views expressed in this paper are those of the individual authors and do not necessarily reflect the view or policy of the National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention.

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