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Crash Risk in General Aviation

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IN THE AFTERNOON OF OCTOBER 11, 2006, A PRIVATE PLANE crashed into an apartment complex in Manhattan, killing the pilot, New York Yankees pitcher Cory Lidle, and his flight instructor Tyler Stanger. The impact destroyed the 4-seat, single-engine aircraft and set the building on fire. The crash scene brought aviation safety back to national headlines.[1] In this article, we examine the crash risk of private flights, identify major factors influencing survival in aviation crashes, and discuss possible approaches for improving the safety of general aviation.

Crash Rates

Civilian aviation generally can be divided into 2 groups: commercial and noncommercial flights.[2] Commercial flights transport individuals and goods to generate revenue; they include operations of major airlines, commuter air carriers, and air taxis. Noncommercial flights, usually called general aviation, encompass a wide array of activities—emergency medical services (EMS), sightseeing, flight training, traffic reporting, aerial surveys, search and rescue, crop dusting, firefighting, logging, recreation, and personal or business use. General aviation aircraft range from small private airplanes and business jets to helicopters, hot-air balloons, and gliders.

Currently, there are approximately 228 000 active private pilots and 220 000 registered general aviation aircraft in the United States; 93% of the aircraft are planes, 4% are rotorcraft, and 3% are nonmotorized craft such as gliders.[3] From 2002 through 2005, general aviation, with an annual average of 1685 crashes and 583 deaths, comprised 91% of all aviation crashes and 94% of all aviation fatalities.[4] The fatal crash rate for general aviation, 1.31 fatal crashes per 100 000 flight hours, is 82 times the rate for major airlines (0.016).[3] This difference in crash rates has persisted over many decades.

Risk Factors for Crash Involvement

Due to their relatively small aircraft size and low altitude, general aviation flights are especially vulnerable to adverse weather conditions. Flight procedures vary with weather conditions. Visual flight rules regulate procedures for flight under visual meteorological conditions (defined as a ceiling of 1000 feet and 3 miles of visibility), with the guiding principle of "see and avoid." Flight under reduced visibility is governed by instrument flight rules, for which the navigation and control of the aircraft are performed using instruments. Although commercial flights are almost always operated under instrument flight rules, general aviation pilots often fly under visual flight rules and may not have the necessary training for flying under instrument meteorological conditions. For pilots without instrument training, flying from visual flight rules into instrument meteorological conditions is a perilous scenario. A case-control study revealed that having been initially licensed after age 25 years and not having an instrument rating (ie, not being qualified for flying under instrument flight rules) are each associated with a 4-fold increased risk of being in a general aviation crash in instrument meteorological conditions.[5] Partly reflecting inadequate training and flight experience, pilot error is a contributing factor in 85% of general aviation crashes compared with 38% of airline crashes.[6]

Other environmental factors (eg, airport features, wires, and terrain) also play an important role in general aviation safety. Flying is especially hazardous in Alaska, where the crash rate per flight hour for general aviation is nearly 3 times the national average.[7]

A considerable body of research literature on pilot characteristics and crash risk exists.[8] Alcohol-impaired flying is a well-established risk factor for general aviation crashes.

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In the 1960s, alcohol reportedly was involved in more than 30% of fatal general aviation crashes.[9] Experimental studies conducted in flight simulators indicate that alcohol, in doses as low as 0.02 g/dL, can impair piloting skills, such as the ability to detect angular motion and changes in the oil pressure gauge.[10] The impairment in pilot performance increases with blood alcohol concentrations (BACs) in a dose-response fashion. In a study involving actual flights, Billings et al[11] reported that when BACs reached the level of 0.12 g/dL, pilots lost control of the aircraft in 16 of 30 flights. Consequently, the Federal Aviation Administration (FAA) has implemented alcohol education programs and adopted a zero-tolerance alcohol policy. Currently, federal aviation regulations prohibit any person from acting as a crew member within 8 hours after consuming any alcoholic beverage or while having a BAC of 0.04 g/dL or higher. The legal alcohol limit for pilots, 0.04 g/dL, was promulgated in 1985 when it was considered the lowest level that could be reliably measured by testing equipment.[9]

In 1990, the FAA amended regulations regarding background checks on pilots for alcohol-related motor vehicle convictions, requiring pilots to provide a written report of each alcohol-related traffic offense within 60 days of the conviction. Flying privileges can be suspended or revoked if a pilot has had 2 or more convictions for driving under the influence in the past 3 years. A recent cohort study indicated that a history of driving while intoxicated is a valid risk marker for general aviation pilots. After adjusting for age, sex, and flight experience, the study showed that a history of driving while intoxicated was associated with a 43% increased risk of aviation crash involvement.[12] Following intensive research and interventions, the proportion of alcohol involvement in fatal general aviation crashes has decreased progressively from more than 30% in the early 1960s to about 8% today.[13]

Sudden incapacitation of the pilot is a critical safety issue for general aviation flights, which, unlike commercial flights, usually do not have a co-pilot who could take control of the aircraft in an emergency. Cardiovascular disease, particularly acute myocardial infarction, is the leading cause of in-flight incapacitation. The incidence rate of sudden incapacitation due to cardiovascular disease for general aviation pilots is estimated to be 1.7 crashes per 100 000 pilots per year and increases with pilot age.[14] However, less than 1% of general aviation crashes are attributable to sudden incapacitation resulting from medical emergencies.[14]

Other known or suspected risk factors for general aviation crashes include pilot inexperience,[5,12] older age,[12] male sex,[12] nonconformist flying behavior (measured by an index of noncompliance with generally accepted flying procedure),[15] and prior aviation crash and violation records.[5,16]

Risk Factors for Crash Fatality

Most general aviation crashes do not result in fatalities. Factors influencing occupant survival in aviation crashes have been studied extensively.[17-20] Emerging from these studies are 4 major environmental and pilot-related risk factors for crash fatality: aircraft fire, instrument meteorological conditions, off-airport location, and failure to use safety restraints. Aircraft fire is the single most important determinant of occupant survival in aviation crashes, regardless of the type of flight or aircraft. In one study, the crash fatality rate (defined as the proportion of crashes resulting in ≥1 deaths) for general aviation crashes was 15% in the absence of fire and 69% when there was a fire.[19] Aircraft fire is involved in 13% of general aviation crashes but accounts for 40% of crash fatalities; the adjusted odds ratio of pilot fatality associated with aircraft fire is 14 in general aviation crashes.[19]

The risk of fire after a crash can be reduced through appropriate aircraft design. Crash-resistant fuel systems, designed to sustain high-impact forces without rupture and leakage, have virtually eliminated postcrash fire and thermal fatalities in US Army helicopter crashes.[21] This technology is also effective in preventing fires when applied to civil helicopters, although to a lesser extent than in US Army helicopters due to a weaker standard for civil helicopters.[22]

Adverse weather conditions increase the chance of a crash and are important determinants of crash outcome. General aviation crashes occurring in instrument meteorological conditions are more likely to be fatal than crashes in visual meteorological conditions. Although representing only 9% of general aviation crashes, instrument-condition crashes account for 28% of pilot fatalities.[19] Adverse weather may increase the risk of fatality in aviation crashes in several ways. First, crashes occurring in conditions of degraded visibility may involve considerably greater impact forces than crashes in visual conditions because the pilot has less warning of impending impact. Second, instrument conditions may hamper search and rescue efforts. And third, extremely low or high temperatures may pose a significant risk to crash survivors, particularly those injured, while waiting for rescue.

The risk of fatality following a crash also depends on the crash location. Overall, 46% of general aviation crashes occur at airports.[19] The crash fatality rate for general aviation crashes occurring away from airports is 36% compared with 6% for crashes at airports.[19] Like weather, location may influence survival through several pathways. Off-airport crashes are more likely to involve high-velocity, uncontrolled impacts than on-airport crashes. Locations away from airports may lengthen and severely complicate search and rescue attempts, including fire-fighting and EMS.

Not wearing safety restraints, including lap belts and shoulder restraints, is another risk factor for pilot fatality. A study of commuter and air taxi crashes found that those not wearing shoulder restraints were nearly 4 times as likely to die as those wearing them.[17] Research has confirmed that safety restraints are also a significant protective factor for pilots in general aviation crashes.[18] Recently, seatbelt airbags have become standard equipment in many new general aviation aircraft. The devices, available also as retrofit kits, combine airbags with restraint systems that have integrated lap belts and shoulder belts and offer improved protection for the head and neck.[23]

The general aviation crash fatality rate has remained at about 19% for the past 20 years while the overall airline crash fatality rate has declined from 16% from 1986 through 1995 to 6% from 1996 through 2005.[4,24] The higher fatality rate for general aviation crashes may be because such aircraft are not as able to withstand impact forces and protect occupants from death and severe injury as commercial aircraft are. In recent decades, while major airlines have improved seat strength, revised exit row configurations, and used more fire retardant materials, few improvements have been made in general aviation aircraft, in part, because federal regulations only require safety improvements for entirely new aircraft models. A corresponding policy for automobiles would have meant that Volkswagen Beetles could have been sold without seatbelts for decades after federal regulation required them in all new cars.

General Aviation and Public Safety

General aviation accounts for the vast majority of aviation crashes and casualties. Although crash rates have decreased somewhat, the crash fatality rate of general aviation has not changed in the past 20 years. Since the September 11, 2001, attacks, aviation safety efforts have centered on improving aviation security, including the security of small airports and airstrips used primarily by general aviation.

Besides being a public safety concern, general aviation intersects with medicine directly in at least 2 ways. First, transporting patients from crash sites and between medical facilities is more hazardous than generally recognized, and EMS flight crew members have an occupational injury death rate that is 15 times the average for all occupations.[20] Despite 1 EMS helicopter in 3 being likely to crash during a life span of 15 years, few EMS helicopters have crash-resistant fuel systems.[20] Second, physician pilots crash at a higher rate per flight hour than other pilots.[25] It is possible that physicians are more likely than other pilots to buy high-performance aircraft that require more time for mastery than their schedules may allow. In addition, physicians may take risks (eg, fly when fatigued or in bad weather) in order to meet the demands of a busy medical practice. From 1986 through 2005, a total of 816 physician and dentist pilots were involved in general aviation crashes; of them, 270 (33%) were fatally injured. Physician and dentist pilots accounted for 1.6% of all general aviation crashes and 3.0% of pilot fatalities (Carol Floyd, BS, National Transportation Safety Board, written communication, February 2, 2007).

Conclusions

In summary, general aviation crashes are a little-recognized public safety problem even though they account for the great majority of aviation deaths. To improve the safety of general aviation, interventions are needed to improve fuel system integrity and restraint systems, enhance general crashworthiness of small aircraft, and reduce weather-related crashes through pilot training and avionics technology. The FAA and the National Transportation Safety Board should place high priority on reducing general aviation crashes and allocate adequate resources for developing and implementing effective intervention programs.

Financial Disclosures: None reported.
Funding/Support: This work was funded in part by grants R01AA09963 and R01AG13642 from the National Institutes of Health and grant CCR302486 from the Centers for Disease Control and Prevention.
Role of the Sponsor: The funding agencies had no role in the preparation, review, or approval of the manuscript.

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