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AN ANALYSIS OF IN-FLIGHT IMPAIRMENT AND INCAPACITATION IN FATAL GENERAL AVIATION ACCIDENTS (1990-1998)

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ABSTRACT

In-flight impairment and incapacitation are defined as states wherein the pilot's ability to effectively control the aircraft is adversely affected. They are of special concern in general aviation given there may be no second pilot to take over the controls. The purpose of the present study was to examine the characteristics of fatal general aviation accidents associated with impairment and incapacitation. A comprehensive review of 2,696 fatal general aviation accidents from 1990-1998 using database records maintained by the NTSB and FAA yielded 216 accidents (8.01%) that had some form of impairment/incapacitation or physiological causes mentioned in the accident report. Impairment due to drugs ($n = 88$, 40.7%) and alcohol ($n = 68$, 31.5%) were the most common causes. Cardiovascular causes were cited in 12.03% ($n = 26$) of the cases. Significant relationships were observed between age and impairment/incapacitation due to alcohol, drugs, and cardiovascular causes. Some disparities were observed between the prevalence of alcohol in toxicology samples and alcohol impairment being cited in the accident report as a contributory factor. The analysis provides some insight into the possible causes of pilot impairment and incapacitation in general aviation. Education and risk management training may serve as effective interventions.

INTRODUCTION

In-flight incapacitation is characterized by any state that affects pilots' health during the performance of their duties, preventing them from performing normal operations and coping with emergency situations (Martin-Saint-Laurent, Lavernhe, Casano, & Simkoff, 1990). The issue of in-flight incapacitation has been the subject of intense interest to the aviation medical community and safety professionals, because of its potential to cause a fatal mishap in the air. Incapacitation in General Aviation (GA), where generally there is no copilot, poses a greater threat to flight safety compared to a multi-crew environment where the second pilot can take over controls in the event of impairment or incapacitation of the other pilot.

Frequently reported causes of in-flight sudden incapacitation in civil and military pilots are acute coronary events (Leighton-White, 1972; Manning, 1975; Mohler & Booze, 1978; Rayman, 1974), new onset idiopathic epilepsy and physiological

conditions including spatial disorientation, hypoxia, and improper G-protection techniques (Rayman, 1973). A review of the literature reveals that the concern has been primarily limited to incapacitation subsequent to medical causes in general and cardiovascular causes in particular (Rayman & McNaughton, 1983; Booze, 1989). However, in-flight incapacitation subsequent to other physiological conditions or self-imposed stresses (such as alcohol and drugs) can all lead to the same outcome - a fatal aviation accident. It is therefore surprising that not much data exists on incapacitation in GA resulting from causes other than cardiovascular.

While incapacitation, obviously implies the inability of the pilot to control the aircraft, a seemingly less ominous manifestation, would be impairment. Although, not clearly defined in most databases, it presumably differs from incapacitation in the magnitude of deterioration in the ability of the pilot to control the aircraft. While impairment may not impact system safety in other work

environments, it has almost similar connotations in aviation as incapacitation. No study has yet described the composite problem of impairment and incapacitation in GA and the possible outcomes after in-flight impairment/incapacitation.

The quantification of impairment and incapacitation in general aviation is much more difficult than commercial aviation. There may be no witnesses in the aircraft, no electronic aids such as Flight Data Recorder or Cockpit Voice Recorder, and the impact forces may damage the remains, especially of the occupant, beyond any utility value. Identifying incapacitation as a cause (or even discovering the occurrence of incapacitation) in such an accident can be very difficult and may only be surmised from the circumstances preceding the accident. This has been brought out in previous studies, given the fact that trauma, fire, and inattention to detail may mask medical or physiological causes involved in some accidents (Booze, 1989). The purpose of the present study, however, was to examine the causes and characteristics of fatal general aviation accidents that have been found to be associated, either directly or indirectly, with impairment and incapacitation.

MATERIAL AND METHODS

A comprehensive review of all fatal general aviation accidents from 1990-1998 was conducted using database records maintained by the National Transportation Safety Board (NTSB) and the Federal Aviation Administration (FAA). Those accidents attributable at least in part to the aircrew, in which the investigation was complete, and the cause of accident determined were included for analysis. A total of 2,696 fatal accidents met these criteria and of these 216 (8.01%) accidents had some form of impairment, incapacitation, physical impairment or physiological causes mentioned in the accident report.

Autopsy reports (where available) were also analyzed in cases where the NTSB investigators had cited heart attack/other cardiovascular (CVS) or physiological causes as cause of accident. These autopsy reports were obtained from the Medical Statistical Section, Civil Aerospace Medical

Institute (CAMI), Federal Aviation Administration in Oklahoma City.

RESULTS

Impairment/incapacitation due to drugs was present in 40.7% ($n = 88$) of the 216 accidents, followed by alcohol in 31.5% ($n = 68$) of the accidents. Incapacitation/impairment due to heart attack/cardiovascular causes was present in 26 (12.03%) accidents. No cause for impairment/incapacitation was mentioned in 17 (7.87%) accidents. There were 9 (4.16%) accidents involving impairment/incapacitation due to hypoxia in-flight, whereas 4 (1.85%) accidents had impairment/incapacitation due in-flight exposure to carbon monoxide. No description was available in 5 cases of impairment/incapacitation due to organic/other organic causes and 2 cases due to other toxic causes. Three cases of impairment/incapacitation occurred as a result of the pilot suffering a stroke in-flight. There were 4 cases of in-flight impairment due to visual deficiency. There were nine cases with physiological condition documented as the cause; however, the cause was not immediately obvious from the sequence of events or the "probable cause of the accident."

Of the 14 cases where only incapacitation was cited as a cause, the cause remained unknown/undetermined in 5 cases. Among the rest, one of the pilots had transmitted before the accident that "he was not feeling well and had blurred vision." Four of them appear to be cardiovascular in origin in the form of autopsy evidence of coronary atherosclerosis or myocarditis or a history of severe chest pain or taking medications for hypertension. One pilot had been incapacitated as a result of a bird strike on the windscreen.

NTSB accident reports were perused to look for possible causes in the narrative section in cases that had a physiological cause. While one of them obviously appears to be Insulin Dependent Diabetes Mellitus (IDDM) (presence of insulin bottles and syringes), two appear to be cases of hypertension on medications. There were two pilots in whom there was no description of what the physiological condition may have been, both however, occurred during aerial application.

Environmental Conditions and Operation of Flight

Majority of these flights (94.0%, $n = 203$) were being operated under CFR Part 91, whereas 3.2% ($n = 7$) were operating under CFR Part 137 at the time of accident. Almost a third (32.4%, $n = 70$) of these accidents occurred during maneuvering phase of flight, followed by the approach phase in 14.4% ($n = 31$) accidents. Accidents occurring during the cruise phase accounted for 13.0% ($n = 28$) cases, while accidents that occurred during take off and descent phases of flight each accounted for 10.2% ($n = 22$) cases.

Pilot Demographics

Pilots more than age 60 constitute the largest group (19.0%, $n = 41$), whereas pilots younger than 26 years constituted only 7.9% ($n = 17$). Approximately 40.7% ($n = 88$) of the pilots were more than 50 years of age. Information on age was not available in 2 cases. Almost a third (31.9%, $n = 69$) of the pilots had logged more than 2,000 hours of flying, whereas an almost similar percentage 30.6% ($n = 66$) had less than 500 hours of flying. The next highest group was pilots with flying experience between 501-1,000 hours (16.2%, $n = 35$). More than half of the pilots held a Private Pilot License (PPL) (53.7%, $n = 116$) with 20.8% ($n = 45$) holding a Commercial Pilot License (CPL). In 3.2% ($n = 7$) of the accidents, the pilot was not holding a valid pilot license.

Age and Cause of Impairment/Incapacitation

Figures 1, 2, and 3 show the relations between the three major causes of impairment/incapacitation and age. Impairment/incapacitation due to cardiovascular causes shows a gradual increase beyond the age of 30, whereas alcohol and drugs predominate in the middle age groups (41-45 years). There was a statistically significant relation between age and impairment/incapacitation due to alcohol (χ^2 ($n = 214, 8$) = 21.264, $p < 0.006$), drugs (χ^2 ($n = 214, 8$) = 19.930, $p < 0.01$), and cardiovascular causes (χ^2 ($n = 214, 8$) = 20.376, $p < 0.009$).

Cardiovascular Impairment/Incapacitation and Autopsy Findings

Although autopsy reports were not available in almost half of the cases where heart attack or cardiovascular cause was annotated, those available provide sufficient insight. There were 5 autopsies available out of 12 cases of incapacitation due to heart attack. In four of these, the medical examiner conducting the autopsy considered blunt trauma as the primary mechanism of death. One had “cardiovascular” as the cause of death. Similar pattern is observed in cases where the NTSB cause was impairment (heart attack) or other CVS.

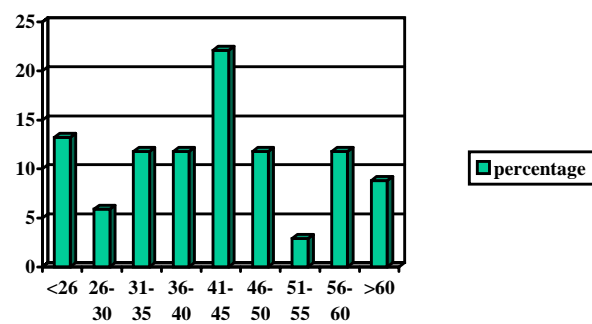


Figure 1. Impairment/incapacitation due to alcohol and age.

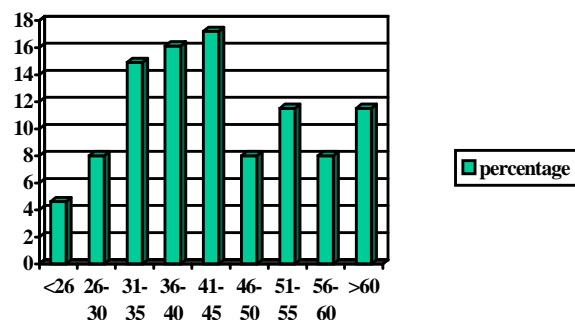


Figure 2. Impairment/incapacitation due to drugs and age.

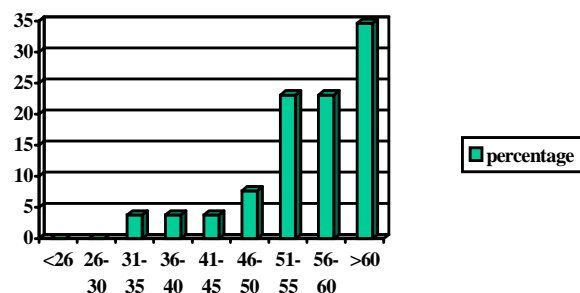


Figure 3. Impairment/incapacitation due to heart attack/cardiovascular causes and age.

Evidence of acute occlusion of the coronary blood vessels was present in only 4 out of the 10 autopsies, with findings of coronary disease in all but one. Autopsy findings suggest that the probable underlying cause in cases where “Other CVS” was mentioned could be coronary heart disease.

DISCUSSION

Despite the low incidence of in-flight incapacitation, the subject has been a cause for concern. Various researchers have used different databases and employed different denominators to estimate the magnitude of the problem of incapacitation in aviation. While Rayman (1973) reported the incidence of fatal accidents due to in-flight sudden incapacitation in the USAF to be about 0.5 per 1,000 pilots for every 1,000 hours of flying, with incidence due to coronary artery disease at 0.01 per 1,000 pilots for every 1,000 hours of flying (Rayman, 1974). Mohler and Booze (1978) provide cardiovascular incapacitation rate of 0.93% of documented fatal GA accidents. All the above, with miniscule numerators compared to enormous denominators belies the adverse potential and consequences of the event in a single pilot operation.

The effects of impairment and incapacitation due to alcohol have generally not been reported in literature. Alcohol at or above the legal limit of 0.04% has generally averaged around 7% of all fatal general aviation accidents (Canfield, Hordinsky, Millett, Endecott, & Smith, 2001). In the present study, alcohol and drugs constitute the most significant causes of impairment leading to fatal aviation accidents. Alcohol can affect attention and signal detection performance (Jansen, de Gier, & Slangen, 1985) besides causing prolongation of reaction time and lowering of a coordination performance (Tagawa, Kano, Okamura, Itoh, Sakurai, Watanabe, & Yanai, 2000). Although, the impairment may not be as catastrophic as other causes, the effect on flying performance can jeopardize flight safety, as has been evident from the data.

There appears to be a disparity between the NTSB investigators attributing alcohol /drug as a cause of impairment and the same being found in

toxicology samples at or above the legal limits (0.04%). CAMI is required to conduct toxicological analyses on specimens from, and special pathologic studies on aircraft accident fatalities (Department of Transportation, 1985). Alcohol was found in 124 cases from 1994 to 1998, with 117 of these in pilots operating under CFR 91 (Canfield et al., 2001). In our data, impairment alcohol was mentioned in only 90 cases by the NTSB investigators. This disparity seems all the more glaring because evidence suggests (Cook, 1997) that aircrew performance may be impaired by alcohol consumption even after their blood alcohol concentration has returned to “zero” (i.e., < 5 mg/dl). Such disparities may possibly influence the causative sequences of various fatal accidents.

The significant relation of cardiovascular conditions with increasing age corroborates findings reported in the aviation literature (Booze, 1989) as well as those reported for the general population (Kannel & McGee, 1985). Analysis of autopsy reports in cases where heart attack and CVS was cited, presents some interesting features. A difference of opinion is possible between the NTSB investigators presumption of impairment due to cardiovascular cause and the medical examiner’s opinion on the cause of death. This could be subsequent to the massive injuries sustained by the pilot due to impact forces, even if, there was in-flight incapacitation leading to loss of control. It may also be difficult at times for the medical examiner to attribute the cause of death as “cardiovascular” with the lack of definitive evidence of an acute occlusion/ myocardial infarction. It is also known that approximately 6% of all patients with acute myocardial infarction, and perhaps four time this percentage of patients with this diagnosis younger than the age of 35 years, do not have coronary atherosclerosis demonstrated by coronary angiography or at autopsy (DeWood, Spores, Notske, et al., 1980). On the other hand, there may be occasions, when the medical examiner documents cardiovascular as a cause of death but the NTSB investigator does not even consider that possibility. This has been brought out in an earlier report (Taneja & Wiegmann, 2001). Such ambiguities in attributing cardiovascular, as the cause of impairment/incapacitation would certainly

affect the incidence/figures that have been so often quoted.

The relations between the major causes of impairment and incapacitation with age are interesting. Alcohol and drugs appear to follow similar patterns with peak in the middle ages. It is difficult to put forward any hypothesis for this, except that with some experience in aviation, there may be a complacency setting in, where one could feel that he or she is experienced enough to “experiment” with flying while intoxicated.

The present analysis provides some insight into the possible causes that may impair or incapacitate a pilot in-flight and thus affect the safety of flight. Alcohol and drugs have continued to be present in about 7% of fatal general aviation accidents and need to be considered in evaluating the total magnitude of the problem of in-flight impairment and incapacitation. Preventive activities, such as educating the pilots on the physiological mechanisms in flight and the effects of subtle illnesses on performance can go a long way in enhancing flight safety. Educating the pilot community on the epidemiology and etiology of cardiovascular illnesses can certainly lead to primary prevention of the disease and decrease the disease burden among the pilot population.

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