

Toxicological Findings from 1587 Civil Aviation Accident Pilot Fatalities, 1999–2003

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Introduction: The prevalence of drug and ethanol use in aviation is monitored by the Federal Aviation Administration (FAA). Under such monitoring, toxicological studies for the 1989–1993 and 1994–1998 periods indicated lower percentages of the presence of controlled substances (illegal drugs) than that of prescription and nonprescription (over-the-counter) drugs in aviation accident pilot fatalities. In continuation, a toxicological assessment was made for an additional period of 5 yr. **Methods:** Biosamples from aviation accident pilot fatalities submitted to the FAA Civil Aerospace Medical Institute (CAMI) are analyzed, and those findings are stored in a database. This database was examined for the 1999–2003 period for the presence of controlled substances (Schedules I–V), prescription/nonprescription drugs, and ethanol in the fatalities. **Results:** Out of 1629 fatal aviation accidents from which CAMI received biosamples, pilots were fatally injured in 1587 accidents. Drugs and/or ethanol were found in 830 (52%) of the 1587 fatalities. Controlled substances from Schedules I–II (SI–II) and Schedules III–V (SIII–V) were detected in 113 and 42 pilots, respectively. Prescription drugs were present in 315 pilots, nonprescription drugs in 259, and ethanol in 101. SI–II substances were detected in 5 of 122 first-class medical certificate-holding airline transport pilots. In addition to the controlled substances, many of the prescription/nonprescription drugs found in the fatalities have the potential for impairing performance. **Conclusions:** Findings from this study were consistent with those of two previous toxicological studies and support the FAA's programs aimed at reducing the usage of performance-impairing substances.

Keywords: controlled substances, ethanol, forensic science, illegal drugs, nonprescription drugs, over-the-counter drugs, post mortem toxicology, prescription drugs.

THE FEDERAL AVIATION ADMINISTRATION'S (FAA's) Office of Aerospace Medicine is tasked with determining the fitness of pilots to fly aircraft and enforcing related drug and alcohol use regulations (3,11). Under this task, specific medical conditions and the use of certain drugs and ethanol are strictly controlled to ensure the safety of the pilots and the general public. The 1988 Aviation Safety Research Act (3) and the U.S. Department of Transportation Order 8020.11B (1) require that the Office of Aerospace Medicine's Civil Aeromedical Institute (now Civil Aerospace Medical Institute; CAMI) assist in assessing the role of potential medical condition-, or drug/ethanol-related performance impairment of pilots in aviation accidents. In this regard, CAMI is also required to conduct special pathological studies and perform toxicological analyses on specimens from aircraft accident fatalities.

Such toxicological analyses of post mortem samples from aviation accident pilot fatalities are useful in de-

termining whether performance impairment from medical condition(s) and/or drug and ethanol usage was a contributory factor in a particular accident. This analytical process includes identification of controlled substances (illegal drugs) of Schedules I–II (SI–II) and Schedules III–V (SIII–V), prescription and nonprescription (over-the-counter) drugs, and ethanol in the post mortem samples. Examples of SI–II substances are amphetamines, cocaine, and marijuana; and of SIII–V substances are benzodiazepines, phentermine, and propoxyphene (14,21). Antidepressants, antihypertensives, and anticonvulsants are examples of prescription drugs (21); and antihistaminics, antipyretics, and decongestants are examples of nonprescription drugs (20).

Including controlled substances and ethanol, several prescription and nonprescription medications are known to affect the central nervous system (17,20,21). For example, first-generation antihistaminics—brompheniramine, chlorpheniramine, diphenhydramine, and doxylamine—cause drowsiness and sedation (4), leading to performance impairment. It has been demonstrated that chlorpheniramine and diphenhydramine have adverse influences on a wide range of cognitive performance tasks (16) and on the complex task of operating an automobile (27), respectively. Studies such as the presence of methamphetamine in toxic concentration in a civil aviation accident pilot fatality (8) and the prevalence of first-generation antihistaminics (9,22), and of selective serotonin reuptake inhibitors (SSRIs; 2) have been reported. Antihistamines were found in approximately 5% of pilot fatalities (9,22), while SSRIs in only 1.5% of the fatalities (2). Previous toxicological studies have indicated relatively low percentages of pilot fatalities wherein controlled substances (illegal drugs) were

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found in comparison to prescription and nonprescription drugs during the time periods of 1989–1993 (5) and 1994–1998 (6). In the present study, the toxicological assessment for the presence of drugs and ethanol was evaluated in civil aviation accident pilot fatalities for an additional 5-yr period of 1999–2003.

METHODS

Post Mortem Biological Specimens

During the investigation of aircraft accidents occurring within the jurisdiction of the United States, autopsied biological samples (blood, urine, liver, kidney, vitreous fluid, and other body specimens) collected from pilot fatalities of civil aircraft accidents are submitted to CAMI for toxicological analyses (3). These aviation accidents encompass accidents involving registered as well as unregistered aircraft. Not all of the pilots involved in these accidents may necessarily have been certified pilots, or may necessarily have been medically certified, to fly an aircraft. Biological sample submissions are coordinated through the FAA's Office of Accident Investigation by the National Transportation Safety Board (NTSB), which is responsible for investigating all U.S. civilian aircraft accidents. The collected samples are submitted to CAMI in the FAA's TOX-BOX evidence containers described elsewhere (10).

Analytical Toxicology

The biological specimens from pilot fatalities are routinely analyzed for the presence of combustion gases (carbon monoxide and hydrogen cyanide), a wide range of illicit, prescription, and nonprescription drugs, and alcohol/volatiles (10). This process entails screening (preliminary) and confirmatory/quantitative analyses. All of these exogenous substances (analytes) in the specimens are analyzed according to the established standard procedures of the CAMI Laboratory using ultraviolet/visible spectrophotometry, fluorescence polarization immunoassay, radioimmunoassay, gas chromatography/mass spectrometry (GC/MS), high-performance liquid chromatography (HPLC), and HPLC/MS. Alcohol/volatile analysis is performed by headspace gas chromatography and radiative energy attenuation method. The analyses are dependent on the nature of analytes, the sensitivity and specificity of analytical methods used, and the availability of sample types and amounts.

Database

The toxicological findings of civil aircraft accident fatalities are electronically stored in a database maintained at CAMI. This CAMI Toxicology Database was examined for the presence of controlled substances (scheduled drugs), prescription and nonprescription drugs, and ethanol in the pilot fatalities from whom post mortem samples were submitted to CAMI during a 5-yr period, 1999–2003. For this period, the database search also entailed the numbers of all aviation accidents and pilot fatalities, including the airman flying and medical certificates of those pilots and the flight

categories of the associated accidents. Pilots that did not have airman flying and/or medical certificates were also part of the study. In the present study, fatalities consist of only pilots—copilots are not included.

Caffeine and nicotine are not incorporated in the list of drugs found in the pilot fatalities. Ethanol is reported in only those cases wherein ethanol concentrations were $\geq 0.04\%$ (w/v), as the FAA regulations (11) forbid the operation of an aircraft by a pilot with a blood ethanol reading of $\geq 0.04\%$ ($40 \text{ mg} \cdot \text{dL}^{-1}$).

Drug Classification (or Grouping) and Pilot Fatality Numbers

Although efforts were made to group controlled substances (scheduled drugs) as classified by the U.S. Drug Enforcement Administration (14), it was sometimes necessary to combine the same types of several substances into one group to minimize the cumbersome nature of tables incorporated in this study. For example, the group barbiturates consisted of butalbital, pentobarbital, and phenobarbital; the group synthetic opiates included hydrocodone, hydromorphone, meperidine, oxycodone, and their metabolites; and the group benzodiazepines entailed α -hydroxyalprazolam, alprazolam, diazepam, midazolam, nordiazepam, oxazepam, and temazepam. Some of the barbiturates included in SII could also be classified in SIII or SIV. Pharmaceutical preparations containing opiates, up to certain concentrations, are classified under SIII, but they fall in the category of SII at higher concentrations, or if they are seized during a drug law enforcement action in any solid or other dosage form. Drugs could be classified as prescription drugs instead of nonprescription drugs, depending on the amounts and formulations of those drugs. It is common in the pharmaceutical industry to categorize a drug in a prescription or nonprescription category based on the nature of pharmaceutical formulation and preparation wherein the drug is present. Therefore, in the present study, drugs found in the fatalities were classified based on their mere presence, even though some of the drugs could be classified differently. In fatalities wherein multiple drugs and ethanol were found, such fatalities were counted more than once—that is, for each drug under its respective category and for ethanol.

RESULTS

During 1999–2003 with respect to airman flying certificates, 1367 (90%) of the total 1524 pilot fatalities were associated with general aviation [Title 14 Code of Federal Regulations (CFR), Part 91] accidents. In these accidents, the highest number of pilots (693) were rated as private pilots and the second highest number of pilots (413) were rated as commercial pilots. Also, there were 201 pilots rated as airline transport pilots.

In relation to airman medical certificate categories, the highest number of pilot fatalities (1350; 90%) of the total 1508 pilot fatalities were associated with general aviation accidents. Of these 1350 fatal accidents, 183 pilots held first-class medical certificates, 437 second-class medical certificates, and 730 third-class medical

TABLE I. DRUGS AND ETHANOL FOUND IN AVIATION ACCIDENT PILOT FATALITIES, 1999–2003.

Year	Pilot Fatalities*					Total with Drugs and Ethanol	All Pilot Fatalities by Year
	SI-II Drug†	SIII-V Drug†	Prescription Drugs	Nonprescription Drugs	Ethanol		
1999	19	8	55	47	26	155	305
2000	22	9	47	57	22	157	334
2001	26	8	61	47	22	164	305
2002	20	9	74	52	16	171	312
2003	26	8	78	56	15	183	331
Total	113	42	315	259	101	830	1587

*More than one drug and ethanol were present in some fatalities. Therefore, those fatalities were counted more than once—that is, for each drug under its respective category and for ethanol. Pilots flying unregistered aircraft were also included.

†Controlled substances—Schedules I–V (SI–V) drugs—as classified by the U.S. Drug Enforcement Administration (14).

certificates. The total of 1508 pilot fatalities does not include medically uncertified pilots.

There were 122 airline transport pilots of the 222 pilots holding first-class medical certificates. In this medical certificate category, there were 78 commercial pilots, 18 private pilots (1 private pilot with the flying certificate of a foreign country), and 4 student pilots. Of the 548 second-class medical certificate holders, 108 pilots were rated as airline transport pilots, 348 as commercial pilots, 86 as private pilots, and 6 as student pilots. In the category of the third-class medical certificate holders, 15 pilots were rated as airline transport pilots, 82 as commercial pilots, 590 as private pilots (5 as private pilots with the certificate of a foreign country), and 48 as student pilots, totaling 735 pilots.

Out of 1629 fatal aviation accidents from which CAMI received biosamples, there were 1587 accidents wherein pilots were fatally injured. Post mortem biosamples were received from these 1587 pilot fatalities, ranging from 305 to 334 fatalities each year during the 5-yr period of 1999–2003 (Table I). The number of fatalities wherein drugs and/or ethanol were detected was 830, which was 52% of the 1587 fatalities. Of the 830 fatalities, prescription and nonprescription drugs were detected in 574 (69%) fatalities, whereas controlled substances (SI–V drugs) were found in 155 (19%) fatalities and ethanol in 101 (12%) fatalities. The percentages of fatalities in which SI–II drugs, SIII–V drugs, and ethanol were detected ranged from 6–9, 2–3, and 5–9%, respectively. The fatality percentage, based on the presence of drug(s)

and/or drug metabolite(s), was approximately 38% of all pilot fatalities.

Based on the category of pilot medical certificate held, there were 1519 fatalities, of which 222 pilots had first-class certificates, 551 second-class certificates, and 746 third-class certificates (Table II). Of the 1519 fatalities, there were 783 fatalities in which drugs and/or ethanol were found. In the 783 pilots, the first-class certificate was held by 79 (10%), the second-class certificate by 270 (34%), and the third-class certificate by 434 (55%). Scheduled drugs and/or ethanol were detected in 241 and prescription and nonprescription drugs in 542. SI–V drugs were found in 15, 53, and 78 pilots holding first-class, second-class, and third-class medical certificates, respectively.

Drugs and/or ethanol were found in 79 of the 221 pilots with first-class medical certificates, in 270 of the 548 pilots with second-class medical certificates, and in 424 of the 730 pilots with third-class medical certificates. SI–V drugs were detected in 7 of the 122 first-class, in 10 of the 108 second-class, and in 1 of the 15 third-class medical certificate-holding airline transport pilots. Of the 585 private pilots with third-class medical certificates, there were 346 (59%) pilots wherein drugs and/or ethanol were detected, and SI–V drugs were present in 62 (11%) of the pilots. None of the SI–V drugs were found in the four student pilots holding first-class medical certificates. Among second-class medical certificate-holding pilots, there were two of the six student pilots wherein SI–V drugs were detected. Of the 48 third-class medical certificate-holding

TABLE II. MEDICAL CERTIFICATE CATEGORIES WITH DRUGS AND ALCOHOL FOUND IN AVIATION ACCIDENT PILOT FATALITIES, 1999–2003.

Medical Certificate Category	Pilot Fatalities*					Total with Drugs and Ethanol	All Pilot Fatalities by Medical Certificate Category‡
	SI-II Drug†	SIII-V Drug†	Prescription Drugs	Nonprescription Drugs	Ethanol		
First class	12	3	25	30	9	79	222
Second class	41	12	95	84	38	270	551
Third class	55	23	170	138	48	434	746
Total	108	38	290	252	95	783	1519

*More than one drug and ethanol were present in some fatalities. Therefore, those fatalities were counted more than once—that is, for each drug under its respective category and for ethanol. For the names of drugs found under the airman medical certificate categories, refer to Tables C, D, and E online (see <http://www.ingentaconnect.com/content/asma/asem>). Pilots flying unregistered aircraft were also included.

†Controlled substances—Schedules I–V (SI–V) drugs—as classified by the U.S. Drug Enforcement Administration (14).

‡These numbers incorporate all pilots who may, or may not, have had airman flying certificates.

student pilots, SI-V drugs were present in 8. Detailed information related to these results can be viewed online*.

With respect to the flight categories of aviation accidents, there were a total of 1570 pilot fatalities. Of these fatalities, there were 821 (52%) fatalities in which drugs and/or ethanol were present. There were 152, 568, and 101 fatalities wherein SI-V drugs (controlled substances), prescription and nonprescription drugs, and ethanol, respectively, were found. Associated with general aviation (Title 14 CFR, Part 91) accidents, there were a total of 1409 pilot fatalities, of which 757 (54%) fatalities were found to contain drugs and/or ethanol. SI-V drugs were detected in 140 of the 757 fatalities. There were no fatalities in which SI-V drugs were found in the flight category of air carrier (Title 14 CFR, Part 121), rotorcraft external load (Title 14 CFR, Part 133), or public use (flights used for governmental agencies). Of these 3 categories, ethanol was detected in only 1 of the total 7 pilots of the CFR Part 121 related accidents and in 2 of the total 20 pilots of the public use related accidents. The percentage of the fatalities with scheduled drugs (controlled substances) was high in the accidents associated with ultralight aircraft (Title 14 CFR, Part 103). There was only one foreign air carrier (Title 14 CFR, Part 129) involving a pilot fatality. In this fatality, no drug or ethanol was detected. Details of these results can be viewed online**.

In general, the number of first-class medical certificate-holding pilots wherein SI-V drugs and/or their metabolites were found was lower than the number of second-class and third-class medical certificate-holding pilots. The number of pilots wherein scheduled drugs were present and who were holding second-class medical certificates was relatively higher than the number of first-class medical certificate-holding pilots, but was less than the number of third-class medical certificate-holding pilots. Marijuana (tetrahydrocannabinol and/or tetrahydrocannabinol carboxylic acid) was detected in the highest number of 21 pilots with third-class medical certificates. Codeine and/or morphine were present in 31 pilots. Of these pilots, 4 held first-class, 13 held second-class, and 13 held third-class medical certificates, while 1 pilot was medically uncertified. Benzodiazepines were also found in 13 pilots holding third-class medical certificates. Synthetic opiates were detected in the fatalities—the fatality number was two in the first-class medical certificate category, and the numbers were nine and eight in the second-class and third-class medical certificate categories, respectively. Including marijuana and benzodiazepines, other drugs were also detected in medically uncertified pilots. Phencyclidine was not detected in any pilot fatality. Findings described herein can be viewed in detail online†.

The presence of prescription drugs and/or their metabolites was relatively more prevalent in the pilots

holding third-class medical certificates than in pilots holding first-class or second-class medical certificates. Diphenhydramine was found in a maximum of 83 (21%) pilot fatalities. The number of fatalities wherein lidocaine and atropine were detected ranked numbers 2 (30; 7%) and 3 (24; 6%), respectively. The presence of antihypertensives and SSRIs also dominated in the fatalities. Details of these findings can be obtained online††.

Nonprescription drugs and/or their metabolites were most prevalent in the pilots who held third-class medical certificates. Pseudoephedrine ranked as the number 1 drug, as this was present in 91 (19%) fatalities, followed by acetaminophen in 84 (17%), phenylpropranolamine in 76 (16%), and ephedrine in 74 (15%). Salicylate was found in 41 (8%) pilots, whereas chlorpheniramine was present in 31 (6%). The presence of nonprescription drugs is detailed online§.

DISCUSSION

Biological samples from pilot fatalities of circa 80% of the total U.S. civil aviation accidents investigated by the NTSB are submitted to CAMI for toxicological evaluation (10). During 1999–2003, samples from a total of 1587 pilot fatalities were received, translating into the equivalent number of fatal aircraft accidents. This number entails registered as well as unregistered aircraft, such as ultralight vehicles. The pilots of such aircraft could also be noncertified to fly aircraft and might, or might not, have had medical certificates. The high percentage (90%) of pilot fatalities observed in general aviation (Title 14 CFR, Part 91) accidents is consistent with the observations made during the first-generation H₁ antihistaminics (9) and SSRIs (2) studies, wherein approximately 90% of pilot fatalities were also associated with general aviation accidents.

Comparison of the toxicological findings of the 1999–2003 period with those of the 1994–1998 period (6) suggested that the incidents of drug and ethanol use in pilots did not increase considerably during the 1999–2003 period. The total pilot fatalities with drugs and/or ethanol were 830 (52%) of the 1587 pilot fatalities during this period, while such fatalities were 803 (48%) of the 1683 pilot fatalities for the 1994–1998 period (6). However, both the 52% and 48% values were higher than that of the 31% value (565 out of 1845 fatalities) for the 1989–1993 period (5). The presence of SI–II drugs increased from 74 fatalities during 1989–1993 and from 89 fatalities during 1994–1998 to 113 fatalities during 1999–2003; an increase was also noted with the prescription drugs in the 1999–2003 study. The presence of SIII–V drugs increased from 28 fatalities during 1989–1993 and decreased from 49 fatalities during 1994–1998 to 42 fatalities during 1999–2003. An increase-and-decrease pattern in the number of fatalities over the years was also observed with the nonprescription drugs. The number of fatalities with ethanol decreased from 146 (5)

* Supplemental data (Table A) can be found online at <http://www.ingentaconnect.com/content/asma/asem>.

** Supplemental data (Table B) can be found online at <http://www.ingentaconnect.com/content/asma/asem>.

† Supplemental data (Table C) can be found online at <http://www.ingentaconnect.com/content/asma/asem>.

†† Supplemental data (Table D) can be found online at <http://www.ingentaconnect.com/content/asma/asem>.

§ Supplemental data (Table E) can be found online at <http://www.ingentaconnect.com/content/asma/asem>.

and 124 (6) to 101 in the current study. The pilot fatality percentage, based on the presence of drug(s) and/or drug metabolite(s), was higher (38%) during 1999–2003 than the percentages observed during the periods of 1989–1993 (27%) and 1994–1998 (32%).

Airline transport-rated pilots holding first-class medical certificates qualify to fly aircraft for transporting passengers and for other purposes, but second-class and third-class medical certificate-holding airline transport pilots do not qualify to transport passengers. Since most of the airline transport and commercial pilots are subjected to random drug testing for the presence of amphetamines, cocaine, marijuana, opiates, phencyclidine, and/or their metabolites (12), the present study examined the positive drug rate based on the airman medical, as well as airman flying certificate classifications. It was found that the percentage of pilots with SI-II drugs in a given medical class (first-class, second-class, and third-class) was approximately within 1% of each other. With respect to airman medical certificate categories, the percentage of fatalities wherein SI-V drugs and ethanol were detected was approximately the same (241 out of 1519 fatalities; 16%) in the present study than was observed (245 out of 1616 fatalities; 15%) in the 1994–1998 study (6). However, prescription and nonprescription drugs during 1999–2003 were found in a higher number of fatalities (542; 36%) relative to the fatalities (520; 32%) reported in the 1994–1998 study. With respect to flight categories, it is clearly evident that the presence of scheduled and prescription drugs dominated in the pilot fatalities associated with general aviation and ultralight flights.

Although the prevalence of scheduled drugs in the fatalities was, in general, consistent with the findings of the previous studies (5,6), the increase in their prevalence, if any, could be attributed to the possibilities of: 1) scientific and technical advances in the sensitivity of analytical detectability; 2) genuine authorized medical use of such drugs; and/or 3) their real abuse. The analytical sensitivity enhanced the detection of not only the parent drugs but also their metabolite(s), even if they were present in low concentrations. Narcotic analgesics found in pilot fatalities could have been administered by emergency health care providers at accident scenes, or at hospitals for pain reduction and/or surgical procedures. However, the presence of illegal drugs (controlled substances)—for example, amphetamine, methamphetamine, 3,4-methylenedioxymethamphetamine, cocaine, and marijuana—could have been attributed to their unauthorized use. Prescription drugs, such as atropine and lidocaine, might have been administered by health care providers for resuscitation. The presence of prescription drugs found in the fatalities reflected the current trends in the popularly dispensed groups of medications—antihypertensives and antidepressants—in the U.S. (18,19,23–26). The use of nonprescription drugs was primarily associated with drug preparations and formulations used to alleviate allergy and cold symptoms.

The percentages of fatalities with ethanol during 1999–2003 on yearly and medical certificate category bases ranged from 4–9%, which were similar to the

numbers reported in the two previous studies (5,6). Since the method used for ethanol analysis does not differentiate ingested ethanol from post mortem ethanol (7), the presence of ethanol in those pilots may not necessarily suggest the consumption of ethanol. In reducing the use of ethanol in pilots, the driving under the influence (DUI)/driving while intoxicated (DWI) rule (13) plays a crucial role under which the FAA monitors DUI/DWI convictions of pilots and takes action to suspend medical certificates where necessary.

Although no pilot fatality in an air carrier (Title 14 CFR, Part 121) related aviation accident was found to be positive for scheduled drugs, it is difficult to assign any significance to this finding due to the small number of CFR Part 121 accidents that occurred between 1993 and 2003. This observation agrees with the FAA drug-testing program's conclusion that less than 1% of those pilots tested under the drug-testing program are positive for illegal drugs (12,15).

Overall, findings from the present study were consistent with those of the two previous toxicological studies (5,6) and support the FAA's programs, including the FAA's drug-testing program, aimed at identifying potentially incapacitating medical conditions and reducing the use of performance-impairing drugs or ethanol (12,15). In addition to scheduled drugs (controlled substances), many of the prescription and nonprescription drugs found in the fatalities have the potential for impairing performance, thereby adversely affecting a pilot's ability to safely fly an aircraft.

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