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Toxicological Findings in Federal Aviation Administration General Aviation Accidents

REFERENCE: Kuhlman, J. J., Jr., Levine, B., Smith, M. L., and Hordinsky, J. R., "**Toxicological Findings in Federal Aviation Administration General Aviation Accidents,**" *Journal of Forensic Sciences*, JFSCA, Vol. 36, No. 4, July 1991, pp. 1121–1128.

ABSTRACT: Blood, urine, and tissue specimens were received from 377 Federal Aviation Administration (FAA) aviation fatalities during fiscal year 1989. Carbon monoxide at less than 10% saturation was found in 94% of the cases, and cyanide at less than 0.5 mg/L was found in 96% of the cases. Ethanol at greater than 10 mg/dL was found in 14.8% of the cases, but only 4.5% were determined to be due to ethanol ingestion from toxicological findings. Excluding nicotine and ethanol, 12.6% of the cases were positive for one or more drugs. Acetaminophen and salicylate were the most frequently found drugs. Cannabinoids were found in 1.3% of the cases and benzoylecgonine in 1.6%. There was minimal use of therapeutic drugs that cause central nervous system depression or stimulation. These results show no consistent pattern of drug involvement in civilian aviation fatalities.

KEYWORDS: toxicology, aircraft, death, drug identification, aviation fatalities

A great deal of literature has been published on epidemiological studies involving the incidence of drugs in drivers. Toxicological findings in driver fatalities have been one approach used to ascertain drug use in drivers. For example, Mason and McBay [*1*] examined 600 driver fatalities in North Carolina over a 3 year period and concluded that although drugs of abuse were detected, ethanol was the only drug which was significantly involved. Caplan et al. [*2*] found that 42% of driver fatalities tested in Maryland over a 10 month period were positive for ethanol, and 17% were positive for other drugs of abuse. In addition, therapeutic agents such as antihistamines, sympathomimetic amines, and beta-blockers were also detected. Similar studies of drug use by drivers across the United States and in other parts of the world have been published [*3–6*].

The quantity of data on drug use by commercial transportation employees is more limited. A study of truck drivers in Tennessee found that 29% of those tested had evidence of alcohol, cannabinoid, cocaine, or stimulant use [*7*]. Moody et al. [*8*] analyzed specimens

The opinions herein are those of the authors and not those of the Department of the Air Force, the Department of Army, the Department of Defense, or the Federal Aviation Administration.
Received for publication on 23 June 1990; revised manuscript received 28 Nov. 1990; accepted for publication 5 Dec. 1990.

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for alcohol and drugs of abuse from 743 individuals involved in railroad accidents. The incidence of drugs detected were cannabinoids (4.3%), cocaine (0.9%), ethanol (0.7%), and opiates (0.7%). Interest in alcohol in general aviation accidents was initiated by Harper and Albers in 1964 [*9*]. Since their report, alcohol, aviation, safety, and pilot education have been given greater emphasis [*10,11*]. Lacefield et al. published a study which includes alcohol and drug data from civilian aviation fatalities in 1975 [*12*]. Ethanol at greater than 0.05 g/dL was found in 8.7% of the cases, and drugs were found in 1.2% of the cases over a seven year period. However, few details regarding methods or types of drugs included in screening regimens were given. Previous studies on ethanol alone had shown that it was present in a similar percentage of aviation fatalities [*13*]

The Federal Aviation Administration (FAA), either independently or on behalf of the National Transportation Safety Board (NTSB), directly contributes to the process of investigating fatalities which occur from civilian aircraft accidents. The investigation includes toxicological analyses of biological specimens from appropriate victims, most notably the pilot, and possibly other members of the flight crew. In fiscal year 1989, these specimens were sent to the Division of Forensic Toxicology, Armed Forces Institute of Pathology, for toxicological analyses. The following is a summary of the data obtained from general aviation accident fatalities over fiscal year 1989.

Methods

From October 1988 to October 1989, the Division of Forensic Toxicology received 377 cases for toxicological testing. A standard testing protocol of carbon monoxide, cyanide, volatiles, and drug screening was performed on all cases if appropriate specimens were received. Specimen collection was done by medical personnel supporting the accident or by local medical examiners. The specimens were usually received frozen from the Civil Aeromedical Institute in Oklahoma City. Case specimens were received, stored, and processed under chain-of-custody. Processing involved noting the condition and quantity of the specimens received, aliquoting the appropriate specimen for each procedure, and storing the remaining case specimens in the freezer at −20°C.

Carboxyhemoglobin determinations were performed using a CO-Oximeter IL-282 or IL-482 (Instrumentation Laboratory Inc., Lexington, Massachusetts). Any sample with a carboxyhemoglobin saturation greater than 10% was confirmed using gas chromatography. A Perkin Elmer Sigma 1B gas chromatograph with a molecular sieve column, thermal conductivity detector, and Valco gas sampling valve was used for confirmation. Carbon monoxide was released in a plastic syringe by the addition of potassium ferricyanide. The headspace from the syringe was introduced into the gas chromatograph. Sample hemoglobin was determined by the CO-Oximeter. The percent carboxyhemoglobin in the sample was calculated from the ratio of carbon monoxide content and carbon monoxide-binding capacity [*14*].

Hydrogen cyanide (HCN) determinations were performed using Conway microdiffusion plates and pyridine-barbituric acid chromogenic reagent [*15*]. Samples were compared to a negative blood standard and a freshly prepared 0.5 mg/L cyanide blood standard. Samples with cyanide concentrations greater than the 0.5 mg/L standard were confirmed using a Hewlett Packard 5880 gas chromatograph equipped with a nitrogen-phosphorous detector (NPD) and a Porapak Q packed column. One millilitre of blood, 0.003% acetonitrile in water (internal standard), and 2 *N* sulfuric acid (H_2SO_4) were pipeted into a headspace vial and crimp cap sealed immediately. The contents were mixed and allowed to equilibrate in a 60°C heating block for 10 min. The samples were injected manually using a 1.0 mL syringe. The ratio of HCN to internal standard for each standard was plotted against blood concentrations. Linear regression analysis of the data was used to construct a best-fit standard plot, and this was used to determine cyanide concentration in case specimens.

Volatile testing was performed using a Hewlett Packard 1939A headspace autosampler and a Hewlett Packard 5880 gas chromatograph containing a flame ionization detector (FID) and an 80/100 Carbopack C/0.2% Carbowax 1500 packed column. The samples were tested for acetaldehyde, acetone, ethanol, 1-propanol, 2-propanol, 1-butanol, 2-butanol, isobutanol, and *tert*-butanol. The internal standard was methyl ethyl ketone.

Drug screening was performed using fluorescence polarization immunoassay (Abbott Laboratories, Diagnostics Div., Chicago, IL), radioimmunoassay (Roche Diagnostic System, Nutley, New Jersey), thin layer chromatography (Toxi-Lab Inc., Irvine, California), and gas chromatography. The radioimmunoassay was performed after acetonitrile precipitation of blood and tissues. The gas chromatographic screen was performed as an extract of blood, urine, or tissue. The extract of the sample was prepared by adding 0.1 *N* potassium hydroxide (KOH), extracting with *n*-butyl chloride, back-extracting with 0.2 *N* H_2SO_4, reextracting with methylene chloride, evaporating, and then reconstituting in methanol. The gas chromatograph was a Hewlett Packard 5880 equipped with a Hewlett Packard 7673 autosampler and an NPD. The column was a J&W Scientific fused silica DB-5 15 m by 0.25 mm by 0.25 μm. The helium carrier flow rate was 1 mL/min, and the oven temperature was 110°C for 1 min, programed at 20°C/min to 200°C, held for 1 min, then programed at 10°C/min to 280°C, and held for 10 min. Identification was made by comparison to retention times of three standards and a control which were run with each batch. Positives were confirmed using the Hewlett Packard 5985 or 5970 gas chromatograph/mass spectrometers.

Results

A total of 351 cases were tested for carbon monoxide. Blood samples were used for analysis when provided; alternately the tissue or fluid containing the most hemoglobin was used. Ninety-four percent (330 cases) had carbon monoxide concentrations of less than 10% saturation, and 6% (21 cases) had carbon monoxide concentrations greater than 10%.

Cyanide was tested in 333 cases. Blood or the tissue containing the most hemoglobin was tested. Ninety-six percent (319 cases) had cyanide levels of less than 0.5 mg/L, and 4% (14 cases) had cyanide concentrations greater than or equal to 0.5 mg/L.

Volatile analysis was performed on 377 cases. At least two specimens were tested for volatiles when possible. A case was determined to be positive if it had an ethanol concentration greater than 10 mg/dL. The other volatiles, acetaldehyde, acetone, 1-propanol, 2-propanol, 1-butanol, 2-butanol, isobutanol, and *tert*-butanol were quantitated and used to determine whether the ethanol found could be due to postmortem formation. There were 14.8% of the cases positive for ethanol. Of the 14.8% ethanol positive cases, 4.5% of cases (30% of ethanol positives) were determined to be due to ethanol ingestion, 8.5% of cases (57% of ethanol positives) were determined to be due to postmortem ethanol formation, and 1.8% of cases (12% of ethanol positives) due to undetermined origin (Table 1). The ethanol positives were further divided into concentration ranges for each category of origination; ingestion, putrefaction, and undetermined (Table 2).

Table 3 lists the drugs which were routinely included in testing batteries in all FAA cases when appropriate specimens were received. Of the 374 cases tested for drugs, 47

TABLE 1—*Volatiles.*

Total cases	377
Total percent positive for ethanol	14.8%
Percent positive due to ingestion	4.5%
Percent positive due to putrefaction	8.5%
Percent positive of undetermined cause	1.8%

TABLE 2—*Ethanol ranges.*

Ethanol Range, mg/dL	No. of Cases	Probable Ingestion	Probable Putrefaction	Undetermined
10 to 50	36	22% (8)[a]	64% (23)	14% (5)
51 to 100	10	40% (4)	40% (4)	20% (2)
>100	10	50% (5)	50% (5)	0%

[a]The numbers in parentheses indicate the absolute number of cases.

TABLE 3—*Drugs included in routine drug screening.*

Antidepressants	Ethchlorvynol
Amitriptyline	
Amoxapine	Meprobamate
Desipramine	
Doxepin	Methaqualone
Imipramine	
Maprotiline	Narcotic analgesics
Nortriptyline	Meperidine
	Methadone
Antihistamines	Pentazocine
Brompheniramine	Propoxyphene
Chlorpheniramine	
Diphenhydramine	Nicotine
Doxylamine	
	Nonnarcotic analgesics
Barbiturates	Acetaminophen
Amobarbital	Salicylate
Butalbital	
Pentobarbital	Opiates
Phenobarbital	Codeine
Secobarbital	Hydrocodone
	Hydromorphone
Benzodiazepines	Morphine
Alprazolam	Oxycodone
Diazepam	
Flurazepam	Phencyclidine
Nordiazepam	
Oxazepam	Phenothiazines
	Chlorpromazine
Cardiac	Promethazine
Lidocaine	Prochloroperazine
Procainamide	Thioridazine
Cannabinoids	Phenytoin
CNS stimulants	Sympathomimetic amines
Amphetamine	Phenylpropanolamine
Methamphetamine	Pseudoephedrine
Phentermine	
Cocaine	
Benzoylecgonine	
Cocaine	

cases were positive for one or more drugs, excluding nicotine and ethanol. This represents a 12.6% positive rate. There were 12 cases which were positive for 2 to 3 drugs, and 3 cases were positive for greater than 3 drugs. Tables 4 and 5 list the numbers of abused and therapeutic drugs found.

Discussion

It is not within the scope of this discussion to predict whether any of these findings were the major cause or a contributing factor to any aircraft accident. No history or circumstances about the accident was received on any case, and it is unknown whether therapeutic drugs found were prescribed or given postaccident in life-support efforts.

Carbon monoxide and cyanide do not appear to be major factors in these overall findings. Only 6% of the cases had carbon monoxide concentrations greater than 10% saturation, and 4% had cyanide concentrations in excess of 0.5 mg/L. Several of the elevated cyanides are likely due in part to postmortem cyanide production [*16*].

The overall positive ethanol rate was 14.8%, using 10 mg/dL as a cutoff. In order for the ethanol concentrations to be compared with previous FAA ethanol findings, a cutoff of 40 mg/dL was used. Twenty-eight cases had concentrations greater than or equal to 40 mg/dL. This represents an overall positive ethanol rate of 7.4%. This rate is higher than recent FAA annual averages (Table 6). If Table 2 is adjusted to a cutoff of 40 mg/dL, and only ethanol determined from the toxicological findings to be due to ingestion is used, the positive ethanol rate is 2.9% (Table 7).

Consideration of postmortem ethanol formation is important when interpreting ethanol data. In aviation fatalities, it is not infrequent that the accident occurs in a remote area, and it may be several hours to several days before the bodies are found, thus increasing the probability that postmortem ethanol formation will occur. It is important that the proper specimens be collected and that more than one sample be tested for ethanol. By considering ethanol results from multiple samples, the condition of the samples and the

TABLE 4—*Abused drugs detected.*

Drugs	Number
Cannabinoids	5
Benzoylecgonine	6
Morphine	1
Amphetamine/methamphetamine	0
Phencyclidine	0

TABLE 5—*Therapeutic drugs detected.*

Drugs	Number
Antidepressants	3
Antihistamines	2
Barbiturates	3
Benzodiazepines	7
Cardiac	4
CNS stimulants	2
Nonnarcotic analgesics	29
Nicotine	18
Opiates	4
Phenothiazines	1
Sympathomimetic amines	6

TABLE 6—*Federal Aviation Administration ethanol findings* [17] *using a ≥40 mg/dL cutoff.*

Year	Percent
1977	8.6
1978	8.3
1979	5.7
1980	6.5
1981	6.5
1982	6.9
1983	7.0
1984	4.8
1985	4.9
1986	4.2
1987	5.5
1988	6.4
Mean	6.3

TABLE 7—*Ethanol ranges adjusted to 40 mg/dL cutoff.*

Ethanol Range, mg/dL	No. of Cases	Probable Ingestion	Probable Putrefaction	Undetermined
40 to 50	8	25% (2)	75% (6)	0%
51 to 100	10	40% (4)	40% (4)	20% (2)
>100	10	50% (5)	50% (5)	0%

presence of C_3 and C_4 alcohols, reasonably good predictions can be made of the contribution of putrefaction to the measured ethanol concentrations. A typical example of postmortem ethanol formation for specimens with slight putrefaction are shown below:

	acetaldehyde	ethanol	1-propanol
blood, mg/dL	<5	56	6
urine, mg/dL	<5	<5	<5

This is contrasted with an example of ethanol due to ingestion in which the specimens were in good condition:

	acetaldehyde	ethanol
blood, mg/dL	<5	23
urine, mg/dL	none found	33

Considering all of the FAA cases, no pattern of consistent drug use was found. There appears to be minimal use of abused drugs (Table 4) with only 5 cases positive for cannabinoids (1.3%) and 6 cases for benzoylecgonine (1.6%) out of 374 cases tested for drugs. The most frequent drugs found were salicylate in 16 cases and acetaminophen in 13 cases. There was minimal use of therapeutic drugs which cause central nervous system (CNS) depression or stimulation. The two CNS stimulants found were phentermine and methylphenidate.

Drug use among general aviation pilots is less prevalent than for trucking industry employees according to a recent study of drug use in the trucking industry [7]. Marijuana use was 15% in the trucking industry compared with 1.3% found in this study. Cocaine use was 2% in truckers, and no parent cocaine was found in aviation, but 1.6% were positive for benzoylecgonine. It should be noted that the trucking survey was a random voluntary survey; whereas in this study, all pilots were fatalities.

In summary, this study has presented drug and ethanol usage by civilian general aviation pilots. It shows no consistent pattern of drug use. Better specimen collection and selection along with the increasing refinement of toxicology testing procedures may demonstrate different patterns of drug use in future years. Positive ethanol cases were slightly higher than in the recent past, but when corrections were made for postmortem ethanol formation, the positive ethanol rate was lower. Previous data did not attempt to exclude ethanol due to postmortem formation. Future criteria to account for postmortem ethanol formation will improve statistics on the use of ethanol by pilots and probably show that that prevalence of ethanol use is lower than currently suspected. Data from field investigations and retrospective preaccident histories will also be critical in resolving the source of alcohol in toxicological findings that are equivocal for ingestion.

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