Dennis V. Canfield,[1] *Ph.D; Thomas Kupiec,*[1] *M.Ed.; and Edwin Huffine,*[1] *M.S.*

Postmortem Alcohol Production in Fatal Aircraft Accidents

REFERENCE: Canfield, D. V., Kupiec, T., and Huffine, E., **"Postmortem Alcohol Production in Fatal Aircraft Accidents,"** *Journal of Forensic Sciences*, JFSCA, Vol. 38, No. 4, July 1993, pp. 914–917.

ABSTRACT: During 1989 and 1990, the Civil Aeromedical Institute received specimens from 975 victims of fatal aircraft accidents. The maximum concentration of ethanol allowed under FAA regulations (0.04%, 40 mg/dL) was exceeded in 79 of these cases (8%). It was determined based on the distribution of ethanol in urine, vitreous humor, blood, and tissue that 21 of the positive cases (27%) were from postmortem alcohol production. Twenty-two of the positive cases (28%) were found to be from the ingestion of ethanol. In 36 cases (45%), no determination could be made regarding the origin of the ethanol. In two cases, postmortem alcohol production exceeded 0.15% (150 mg/dL).

The opinion held by some toxicologists that postmortem alcohol production can be inferred from the presence of acetaldehyde, acetone, butanol, and other volatiles was found to be incorrect. Several cases with postmortem ethanol had no other volatiles. Volatile compounds were found in several cases where no ethanol was present. In addition a case was found in which the relative ethanol concentrations in blood, bile, and vitreous humor were solely consistent with the ingestion of ethanol, but acetaldehyde, acetone, and 2-butanol were also found in blood. This clearly indicates that the presence or absence of other volatiles does not establish postmortem ethanol production.

KEYWORDS: toxicology, postmortem alcohol, aircraft accidents, ethanol

Ethanol found in the blood of a pilot is a significant factor in determining the possible cause of an aircraft accident. However, the interpretation of ethanol in postmortem specimens is complicated by the presence of ethanol produced after death. Previous authors [*1*,*6*] have pointed out the dangers of interpreting ethanol in postmortem samples. Corry [*1*] warns the forensic scientist to "bear in mind that specimens of human tissue containing micro-organisms, particularly specimens taken from corpses, may contain ethanol produced by microbial fermentation, and that extreme caution should be exercised when assessing the significance of postmortem ethanol."

Many papers have been published on postmortem ethanol production [*1–15*]. In these papers various procedures for determining postmortem ethanol production have been proposed. The presence of volatiles other than ethanol has been suggested [*2*] as an indicator of postmortem ethanol. The ratio of ethanol in blood to other specimens has been proposed [*5*,*6*] as another way of differentiating between ingested and postmortem

Received for publication 27 July 1992; revised manuscript received 9 Nov. 1992 and 15 Jan. 1993; accepted for publication 19 Jan. 1993.

[1]Manager, Toxicology and Accident Research Laboratory; Senior Forensic Chemist; and Forensic Chemist, respectively, Forensic Toxicology Research Section, Civil Aeromedical Institute, Federal Aviation Administration, Department of Transportation, Oklahoma City, OK.

Copyright © 1993 by ASTM International

synthesis of ethanol. Several investigators [*5,6,12*] have shown that vitreous humor and urine do not suffer from postmortem ethanol production to any significant extent. Therefore, finding ethanol in urine or vitreous humor would generally indicate the ingestion of ethanol. Vitreous humor will normally have about 12% [*5*] more ethanol than blood if the system is in the postabsorptive phase. Ethanol in urine will normally be about 25% [*16*] or greater than the level of ethanol found in blood assuming no ethanol ingestion for at least 20 min prior to sample collection. Levels of ethanol above certain concentrations have been used by some to infer the presence of ingested ethanol. In several cases concentrations such as 0.02% (20 mg/dL), 0.15% (150 mg/dL) and 0.20% (200 mg/dL) have been suggested [*1,8,9*] as maximum levels of ethanol for postmortem ethanol production.

The Forensic Toxicology Research Section (FTRS) at the Civil Aeromedical Institute (CAMI) receives specimens from most of the fatal aircraft accidents that occur in the United States. Collection and shipment of specimens from these accidents are sometimes delayed and the possibility of postmortem ethanol production does exist. Severe damage to the body often exposes specimens to microorganisms that can produce ethanol under the proper circumstances (temperature, time, and nutrients). A study was undertaken to determine the incidents of postmortem ethanol in specimens received by the laboratory.

Method

Specimens were collected by local pathologists and placed in evidence containers provided by the FAA Forensic Toxicology Research Section. Blood is submitted in 10 mL vacutainers containing 25 mg of sodium fluoride and 20 mg of potassium oxalate. These samples were refrigerated and shipped to CAMI by overnight air. Upon receipt the specimens were inventoried and prepared for analysis by a contract laboratory, the Armed Forces Institute of Pathology. The results of these tests were sent to the FTRS, the data were scanned with a SCANTRON optical card reader into a computer program developed by the Forensic Toxicology Research Section for storing, retrieving, and analyzing toxicology data. Of the various recommendations in the literature, we postulated postmortem ethanol was optimally inferred from the absence of ethanol in urine and/or vitreous humor coupled with a positive ethanol in blood or tissue. All cases with a blood ethanol concentration equal to or more than 0.04% (40 mg/dL) were considered positive, as defined by Federal Aviation Regulation 14 CFR 91.11.

In 1989 and 1990, the Forensic Toxicology Research Section reviewed ethanol test results from 975 aviation fatalities to determine the extent of postmortem ethanol production. Volatiles were identified and quantitated by the contract laboratory using headspace gas chromatography.

Methanol, acetone, 1-propanol, acetaldehyde, t-butanol, 1-butanol, 2-butanol, 2-propanol, and isobutanol were screened at an LOD of 1 mg/dL.

Results

The maximum concentration of ethanol allowed under FAA regulations 0.04% (40 mg/dL) was exceeded in 79 of the 975 cases (8%). Twenty-one of the 79 cases (27%) were determined to be from postmortem ethanol production based on the finding of ethanol in blood but not in vitreous humor or urine. In two of these cases, postmortem ethanol production exceeded 0.15% (150 mg/dL). Twenty-two of the positive cases (28%) were found to be from the ingestion of ethanol based on the ratio of ethanol in blood, urine, and vitreous humor. No vitreous humor or urine was submitted in 36 positive alcohol cases (45%), therefore no determination could be made regarding the origin of the ethanol found in blood or tissue (Table 1).

TABLE 1—*Analysis of source of postmortem alcohol in 975 cases.*

Description	1989	1990	Total
Total cases	461	514	975
Total cases ≥ 0.04% (40 mg/dL)	39(8%)	40(8%)	79(8%)
Postmortem ethanol	13(33%)	8(20%)	21(27%)
Ingested ethanol	8(21%)	14(35%)	22(28%)
Unknown origin for ethanol	18(46%)	18(45%)	36(45%)

Volatiles other than ethanol were found in 13 cases with postmortem ethanol, 9 cases with ingestion of ethanol, 33 cases with ethanol of an unknown origin, and 14 cases without any ethanol (Table 2).

Discussion and Conclusions

Vitreous humor and urine were submitted in only 55% of the positive cases. Therefore, only 28% of these cases could be clearly identified as containing ingested ethanol and 27% as postmortem ethanol. The number of confirmed positive cases with ingested ethanol is much smaller than we anticipated. We must increase the awareness of local pathologists and investigators to the need for collecting and submitting urine, vitreous humor, and other specimens to aid in differentiating between postmortem and ingested ethanol.

The presence or absence of volatiles, other than ethanol, does not of itself provide sufficient information needed to determine the origin of ethanol found in most postmortem samples. Table 2 shows that other volatiles can be found when there is no postmortem ethanol production. Postmortem ethanol can be found in cases where no other volatiles were found.

It has been suggested by some [*1,8,9*] that one can assume the ingestion of ethanol when the ethanol concentration exceeds certain levels, such as 0.020% (20 mg/dL), 0.150% (150 mg/dL), or 0.200% (200 mg/dL). The data collected in this study show that postmortem ethanol concentrations occasionally exceed these values. The concentration of ethanol in postmortem blood, in the absence of additional information, cannot be used with any degree of certainty to verify the ingestion of ethanol. The number of unknown variables in the production of postmortem ethanol makes it difficult to state unequivocally that the ethanol level in a specimen is above that which would be expected from a postmortem specimen. Specimens from 1989 and 1990 showed postmortem ethanol ranging in concentration from our cutoff of 0.01% (10 mg/dL) to 0.18% (180 mg/dL). In 1991 this laboratory analyzed a case with postmortem ethanol in excess of 0.30% (300 mg/dL) in blood and no ethanol in vitreous humor or urine.

TABLE 2—*Relationship of ethanol origin and presence of other volatiles.*

Description	1989	1990	Total
EPV	10	3	13
EIV	6	3	9
EUV	23	10	33
NEV	3	11	14

EPV = Postmortem ethanol and other volatiles.
EIV = Ingested ethanol and other volatiles.
EUV = Unknown origin of ethanol and other volatiles.
NEV = Other volatiles and no ethanol.

References

[1] Corry, J. E. L., "A Review Possible Sources of Ethanol Ante- and Post-mortem: Its Relationship to the Biochemistry and Microbiology of Decomposition," *Journal of Applied Bacteriology*, Vol. 44, 1978, pp. 1–56.

[2] Stone, B. E. and Rooney, P. A., "A Study Using Body Fluids to Determine Blood Alcohol," *Journal of Analytical Toxicology*, Vol. 8, 1984, pp. 95–96.

[3] Nicloux, M., "Dosage of Alcohol in Putrefied Blood and Tissues," *Comptes Rendue des Séances, Société de Biologie* (Paris), Vol. 121, 1935, pp. 1301–1309.

[4] Nicloux, M., "Neoformation of Ethyl Alcohol in Human Cadavers in View of Putrefaction," *Comptes Rendue des Séances, Société de Biologie* (Paris), Vol. 121, 1936, pp. 975–978.

[5] Caplan, Y. H. and Levine, B., "Vitreous Humor in the Evaluation of Postmortem Blood Ethanol Concentrations," *Journal of Analytical Toxicology*, Vol. 14, 1990, pp. 305–307.

[6] Harper, D. R., "A Comparative Study of the Microbiological Contamination of Postmortem Blood and Vitreous Humour Samples Taken for Ethanol Determination," *Forensic Science International*, Vol. 43, 1989, pp. 37–44.

[7] Neil, P., Mills, A. J., and Prabhakaran, V. M., "Evaluation of Vitreous Humor and Urine Alcohol Levels as Indices of Blood Alcohol Levels in 75 Autopsy Cases," *Canadian Society of Forensic Science*, Vol. 18, 1985, pp. 97–104.

[8] Bogusz, M., Guminska, M., and Markiewicz, J., "Studies of the Formation of Endogenous Ethanol in Blood Putrefying In Vitro," *Journal of Forensic Medicine*, Vol. 17, 1970, pp. 156–168.

[9] Spitz, W. U. and Fisher, R. S., *Medicolegal Investigation of Death*, Charles C Thomas, Springfield, IL, 1980, pp. 567–568.

[10] Falconer, B. and Falconer, C., "Postmortal Blood Alcohol in Various Parts of the Vascular System," *Blutalkohol*, Vol. 10, 1973, pp. 328–335.

[11] Luvoni, R. and Marozzi, E., "Ethyl Alcohol Distribution in The Various Organs and Fluids of Cadavers," *Journal of Forensic Medicine*," Vol. 15, 1968, pp. 67–70.

[12] Davis, G. L., Leffert, R. L. and Rantanen, N. W., "Putrefactive Ethanol Sources in Postmortem Tissues of Conventional and Germ-Free Mice," *Archives of Pathology*, Vol. 94, 1972, pp. 71–74.

[13] Blume, P. and Lakatua, D. J., "The Effect of Microbial Contamination of the Blood Sample on the Determination of Ethanol Levels in Serum," *American Journal of Clinical Pathology*, Vol. 60, 1973, pp. 700–702.

[14] Russell, A. B., "Post-Mortem Blood Alcohol Survey in Some Australian States," *The Medical Journal of Australia*, Vol. 2, 1971, pp. 948–951.

[15] Blackmore, D. J., "The Bacterial Production of Ethyl Alcohol," *Journal of the Forensic Science Society*, Vol. 8, 1968, pp. 73–76.

[16] Biasotti, A. and Valentine, T., "Blood Alcohol Concentration Determined from Urine Samples As Practical Equivalent or Alternative to Blood and Breath Alcohol Tests," *Journal of Forensic Sciences*, Vol. 30, No. 1, 1985, p. 194.

Address requests for reprints or additional information to
Dennis V. Canfield, Ph.D.
FAA, AAM 610
P.O. Box 25082
Oklahoma City, OK 73125-5066