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The Use of Marihuana, Ethanol, and Other Drugs Among Drivers Killed in Single-Vehicle Crashes

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ABSTRACT: Marihuana, ethanol, and other drugs are considered by many to be detrimental to the safe operation of motor vehicles. However, direct epidemiological evidence for this belief exists only for ethanol. The goal of this investigation was to determine the incidence of the psychoactive ingredient of marihuana, Δ^9-tetrahydrocannabinol (THC), along with ethanol and other drugs in blood specimens from a carefully defined population of dead drivers. Although THC and other drugs were present in a small number of the blood specimens, the large number of specimens that had high blood ethanol concentrations indicated that alcohol is still the major drug affecting highway safety.

KEYWORDS: toxicology, motor vehicle accidents, alcohol, marihuana

The adverse effect of ethanol on driver performance is one of the most significant factors in highway fatalities. Nationwide, approximately 40 to 55% of the drivers involved in fatal car crashes have blood ethanol concentration equal to or greater than the concentration considered "legally under the influence" (0.10%) [*1*]. Ethanol is the only drug clearly established as being responsible for highway safety problems.

Because of the complex nature of driving it has been difficult to design driver simulator tasks that will accurately assess the effects of drugs on traffic safety. Epidemiological research has suffered from the problems of obtaining blood specimens from operators, inadequate methods for detecting and quantitating drugs, and poorly designed studies. Suitable analyses for drugs in body fluids do not exist for all drugs, and the relationship between concentrations in body fluids and effects are much more complex than for ethanol.

Because of its potent psychoactive effects and ubiquitous nonmedical use, marihuana use could be a potential highway safety problem. There is agreement among the scientific community that marihuana affects perception, cognitive skills, and complex psychomotor performance [*2*]. Modification of these processes would be expected to affect driving a motor vehicle. For example, Moscowitz et al [*2*] demonstrated that marihuana produces decre-

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ments in performance of some tasks in driving simulators in most subjects and Klonoff [3] determined that marihuana affected some aspects of driving in most subjects in actual street driving and on test tracks. However, in both studies not all tasks showed decrements and the performance of some of the subjects improved or did not change. When marihuana is used in combination with ethanol, there seems to be at least an additive effect [4]. Experimental studies like these indicate that marihuana, used alone or in combination with ethanol, has a potential to impair driving skills depending on the dose and the subject.

Although the experimental evidence indicates that marihuana could affect highway safety, the pattern of marihuana use in automobile operators is yet to be established. The frequency of marihuana use by the general driving population is difficult to determine because of legal constraints, difficulties with the analysis of blood for marihuana components, and problems with establishing meaningful population samples. Nevertheless, the observed frequency of marihuana use in certain accident populations can be determined. It is possible to determine the concentrations of the marihuana psychoactive ingredient Δ^9-tetrahydrocannabinol (TCH) [5], the nonpsychoactive THC metabolite 11-nor-Δ^9-tetrahydrocannabinol-9-carboxylic acid [6], and other drugs in blood specimens from fatally injured drivers.

We report the incidence of ethanol, THC, barbiturates, cocaine, amphetamines, opiates, and phencyclidine in the single-vehicle operator fatality population in North Carolina for a one-year period. Positive THC specimens and a group of selected THC negative specimens were also analyzed for the THC metabolite, 11-nor-Δ^9-tetrahydrocannabinol-9-carboxylic acid.

Materials and Methods

Study Population

We accepted only single-vehicle operator fatalities received through the North Carolina Medical Examiner's system between 1 Oct. 1978 and 30 Sept. 1979. Motorcycle and farm equipment operators were excluded. Medical examiner and crash reports established final acceptability for the study. Only cases in which the manner of death was accidental were considered. The criteria for acceptance of the accidental fatalities were: (1) the death occurred within 1 h after the accident (this time restriction was used to minimize metabolic and elimination effects on drug concentrations), (2) the subjects did not receive vigorous medical treatment, and (3) at least 5 mL of suitable blood was collected from either the heart or a vein. We reviewed the entire population of accidental single-vehicle operator fatalities (n = 241) in North Carolina for the one-year period and 169 cases met all criteria.

Sodium fluoride (1%) was added to all bloods as a preservative. After the ethanol determination, the blood was centrifuged to remove cells and the hemolyzed supernatant fluid was stored in a glass vial at −20°C until further analysis.

Drug Screening and Confirmation

Blood was tested for ethanol and other volatiles by diffusion into and reduction of a potassium dichromate solution. Sensitivity for ethanol was <0.02%. All concentrations <0.02% were reported as 0% ethanol. All positive specimens were confirmed and quantitated by gas chromatography [7,8].

Commercially available radioimmunoassay kits (Abuscreen®, Roche Diagnostics, Hoffman-La Roche, Nutley, NJ 07110) were used to test for barbiturates, cocaine and its metabolite benzoylecgonine, opiates, amphetamines, and phencyclidine. The radioimmunoassays identified active drug or metabolite(s) or both, that is, immunological reacting compounds, in blood with sufficient sensitivity to detect therapeutic or recreational concentrations.

Radioimmunoassay positive barbiturate and cocaine specimens were identified and quantitated by gas chromatographic methods [*9,10*].[4] The gas chromatography column retention time was the same for butabarbital and butalbital. Their similar biological activity made additional qualitative efforts unnecessary for the purposes of this study.

THC was screened by a radioimmunoassay specifically designed for use with hemolyzed blood specimens [*5*]. Specimens were tested in duplicate for THC by radioimmunoassay and positive specimens were reanalyzed in duplicate on two occasions and averaged to determine the concentration of THC in the specimen. The cutoff concentration for a positive THC specimen was 3.0 μg/L.

Because of the special problems in the analysis of hemolyzed blood specimens and the low concentrations of THC in the specimens, a nonradioimmunoassay THC confirmatory method could not be found, for example, a gas chromatographic/mass spectrometric method for THC in hemolyzed blood. Therefore, positive THC specimens and some (n = 22) supposed THC negative specimens from the study were analyzed in a blind study for the nonpsychoactive THC metabolite 11-nor-Δ^9-tetrahydrocannabinol-9-carboxylic acid by radioimmunoassay [*6*]. The presumed negative specimens were considered not to contain marihuana constituents because the radioimmunoassay for THC was negative, the subjects age was greater than 50 years (51 to 81), and there was no evidence of marihuana use in the reports.

Statistical Comparison of the Distribution of Ethanol Concentrations

Since ethanol was such a prevalent drug in the study, we compared the distribution of ethanol concentrations in the samples containing THC (n = 10) with the samples that did not contain drugs other than ethanol (n = 149) or cocaine (n = 1). We also compared the ethanol concentration distribution in the samples containing barbiturate (n = 9) with the samples that did not contain drugs other than ethanol. The nonparametric Mann-Whitney U test was used because we could not assume normality of distribution [*11*]. The two-sided null hypothesis was that the sample containing THC or the sample containing barbiturate had the same ethanol concentration distribution as the rest of the sample. The two-sided alternative hypothesis was that the groups differed with respect to ethanol concentration distribution. The chosen critical value of the Mann-Whitney U test statistic z was α = 0.05. The test statistic was corrected for ties.

Results

We accepted 70.1% (n = 169) of the 241 single-vehicle operator fatalities. The reasons for rejection were: (1) the death was more than 1 h after the accident (n = 27, 11.2%), (2) the quantity of blood was less than 5 mL (n = 30, 12.4%), or (3) the blood was unsuitable for examination or the victim received vigorous medical treatment (n = 15, 6.2%).

The study population was mostly male (83.4%), white (82.8%, black 15.4%, American Indian 1.8%), and young (Fig. 1).

We detected no opiate, amphetamine, or phencyclidine in any blood specimen. Tables 1 and 2 summarize the incidence of positive THC (5.9%), barbiturate (5.3%), and cocaine (0.6%) findings.

Thirty-five specimens (20.7%) contained less than 0.2% ethanol and were considered negative. One-hundred-and-thirteen specimens (66.9%) contained more than 0.09% ethanol. The mean (and standard deviation) concentration of ethanol was 0.14% ($\pm$0.10%) (Fig. 2).

The distribution of ethanol concentrations in the specimens containing THC did not differ

[4]The cocaine was confirmed and quantitated at the Center for Human Toxicology, University of Utah, Salt Lake City, UT.

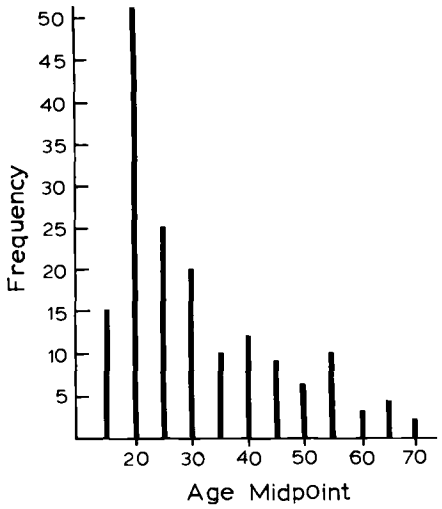

FIG. 1—*Age distribution of drivers killed in single-vehicle crashes. Each bar represents the frequency of each five-year age group.*

TABLE 1—*Barbiturate and cocaine findings.*

A/R/S[a]	BEC,[b] %	Drug and Concentration, mg/L	
1. 42 BM	0.03	phenobarbital	2.6
2. 42 WM	0.25	phenobarbital	1.1
3. 54 BM	negative	phenobarbital	6.0[c]
4. 45 WM	0.21	phenobarbital	4.4
5. 27 WM	0.04	butalbital	0.6
6. 68 WF	0.09	butalbital	1.1
7. 47 WM	0.17	butalbital	2.3
8. 68 WM	negative	pentobarbital	1.1
9. 60 WM	negative	butalbital	2.2
		phenobarbital	17.0
10. 19 WF	negative	cocaine	0.010
		benzoylecgonine	0.190

[a] Age/race/sex.
[b] Blood ethanol concentration in grams of ethanol per 100 mL of blood.
[c] Medical history of epilepsy.

significantly from the distribution in specimens that contained no drugs other than ethanol or cocaine (Mann-Whitney U test $\alpha = 0.05$). The same was true for specimens that contained barbiturates.

Discussion

The absence of opiates, amphetamines, and phencyclidine in the blood of operators showed that in North Carolina those drugs were not a factor in the single-vehicle operator fatalities examined.

The concentration of cocaine and its metabolite, benzoylecgonine, found in one subject must be considered with caution. Cocaine is rapidly converted in blood to benzoylecgonine

TABLE 2—*Marihuana findings.*

A/R/S[a]	BEC[b], %	THC, μg/L	THC-COOH,[c] μg/L
1. 30 WM	0.02	17.2	23.1
2. 24 WM	0.11	13.5	17.8
3. 18 WM	0.17	7.2	32.9
4. 28 WM	0.24	6.2	2.6
5. 24 WM	0.12	5.9	34.3
6. 24 BM	negative	5.3	17.7
7. 22 WM	0.09	5.0	44.8
8. 18 WM	0.16	4.7	44.7
9. 18 WM	0.30	3.9	17.2
10. 32 BM	0.14	3.5	0.0

[a]Age/race/sex.
[b]Blood ethanol concentration in grams of ethanol per 100 mL of blood.
[c]11-Nor-Δ^9-tetrahydrocannabinol-9-carboxylic acid.

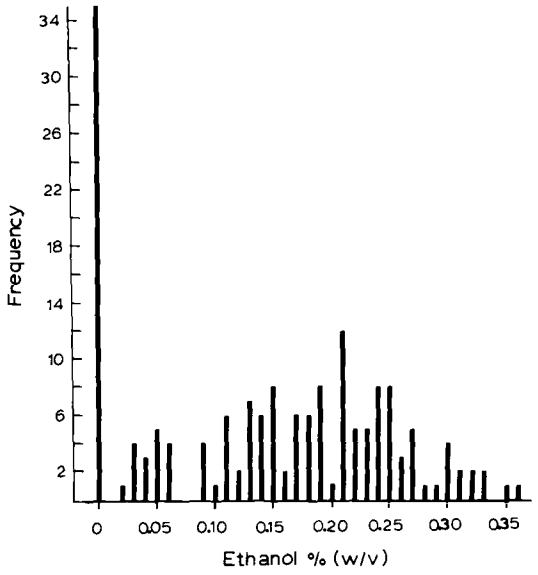

FIG. 2—*Distribution of blood alcohol concentrations. Each bar represents the frequency of each blood ethanol concentration. In most states it is illegal to drive with more than 0.09% alcohol in the blood.*

by pseudocholine esterase [*12*]. The addition of sodium fluoride (an enzyme inhibitor) to blood specimens will inhibit this change. Since we do not know the exact circumstances under which this blood was collected, we must assume that conversion of cocaine to benzoylecgonine may have occurred in the postmortem specimen. The effect of cocaine is unknown.

Except for one case, we found barbiturate blood concentrations below or within a therapeutically acceptable range. One blood specimen contained both an intermediate-acting and a long-acting barbiturate. Both barbiturates were within the therapeutic range, but we considered the combination inconsistent with normal therapy. In one of the nine cases the

medical examiner's report indicated a history of epilepsy. Therefore, the presence of phenobarbital in the blood specimen at a therapeutic concentration suggested acceptable medical treatment. We did not pursue physician records in an attempt to document a medical condition for barbiturate use, but the age (greater than 50 years) of all but one subject may indicate barbiturate use for medical conditions. The high concentrations of ethanol found in four of the cases could lead to unsafe operation of a motor vehicle, regardless of any additional barbiturate effects.

The presence of THC in 5.9% of the cases required careful consideration. Even though THC is primarily responsible for marihuana-produced effects after smoking, there is only a moderate correlation between THC blood concentrations and marihuana-produced subjective effects [*13–15*]. The choice of 3 μg/L of THC as a positive cutoff point was established by consideration of the relationship between subjective self-reported high, physiological effect, and plasma concentrations over time after smoking marihuana cigarettes [*13–17*]. Since our specimens were hemolyzed blood supernatant fluids, the concentration of THC that would be found in a plasma specimen would be greater [*5*]. At concentrations above 3 μg/L most human subjects in marihuana smoking studies show either a subjective or physiological effect; that is, increased heart rate or conjunctival reddening, or both. However, we do not know if these blood concentrations relate to any marihuana-produced effects on driving. Ideally, the presence of THC in these specimens should be confirmed by a nonimmunological technique. Such a method was not available during the time of this study.

However, additional confirmation and information were obtained by analysis of positive THC specimens and a group of supposed THC negative specimens for the nonpsychoactive, THC metabolite, 11-nor-Δ^9-tetrahydrocannabinol-9-carboxylic acid. None of the supposed THC free specimens were found positive for this metabolite. Nine of the ten THC positive specimens were positive for this metabolite. The specimen with the lowest concentration of THC was negative for the metabolite. The very high ratios of 11-nor-Δ^9-tetrahydrocannabinol-9-carboxylic acid to THC found in some of the specimens may indicate marihuana use within several hours, chronic use of the drug, or both [*18, 19*]. The chronic users would be expected to be more tolerant to marihuana-produced effects than occasional or naive users of marijuana [*20*]. Seven of ten THC positive cases also contained concentrations of ethanol equal to or above the amount considered "legally under the influence" in most states. Regardless of any additive effects from THC, this concentration of ethanol indicated an increased risk of an automobile accident. Two of the remaining three THC positive cases did not contain high enough concentrations of THC to interpret their significance. The concentration in one specimen (17.2 μg/L) was high enough to expect the operator to have had some subjective effects. Whether this affected operator safety we do not know.

The most significant finding of the study was that 66.9% of the drivers' bloods contained more than 0.09% ethanol. This is greater than most published figures for ethanol in operator fatalities. This high incidence of specimens with more than 0.09% ethanol possibly resulted from either an increased drinking problem among this group or the careful screening for acceptance to the study.

We compared the ethanol blood concentrations in the samples that contained THC (n = 10) with the samples that contained no drugs other than ethanol (n = 149) or cocaine (n = 1). The results of a nonparametric statistical test showed the ethanol concentration distribution in both groups was the same. Also, the sample containing barbiturate (n = 9) was not different in ethanol blood concentrations. This means that significant amounts of alcohol were found regardless of the presence or absence of other drugs.

Conclusions

Enough alcohol to affect adversely the safe operation of motor vehicles was found in the blood specimens of two thirds of the drivers in this study. In the relatively small number of

instances where other drugs were found, the effects of alcohol would still have predominated because the drug concentrations were relatively low. Of the 169 cases, a possibly significant concentration of pentobarbital was found in one blood, the effect of the amount of cocaine found in another specimen could not be established, and it is not known what the effect of the significant concentration of THC would be on another operator.

Methods and instrumentation do not exist for drug analyses such as the widely available and relatively easy methods and instruments used to determine breath alcohol. Even if they did, there are not sufficient data available to relate blood drug concentrations with their effects on motor vehicle operation.

In this study we only analyzed the blood specimens for a limited number of drugs, consequently many important classes of drugs were not considered, for example, benzodiazipines and methaqualone. However, diverting attention from the many alcohol influenced drivers to the few who might be influenced by other drugs most probably would be counterproductive to highway safety.

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