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Incidence and Toxicological Aspects of Cannabis and Ethanol Detected in 1394 Fatally Injured Drivers and Pedestrians in Ontario (1982–1984)

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ABSTRACT: A comprehensive epidemiological study of the involvement of cannabis and ethanol in motor vehicle fatalities in the Province of Ontario, Canada, is described. The study is based on toxicological analyses of blood and, when available, urine specimens. Ethanol was determined by headspace gas chromatography (GC). For cannabis, the methods employed were radioimmunoassays (RIAs) for screening and gas chromatography/mass spectrometry (GC/MS) for the determination of delta-9-tetrahydrocannabinol (THC) in blood.

The study sample consisted of 1169 drivers and 225 pedestrians. THC was detected in the blood of 127 driver victims (10.9%) in concentrations ranging from 0.2 to 37 ng/mL, with a mean of 3.1 ± 5.0 ng/mL. Ethanol was found in 667 driver victims (57.1%), in concentrations ranging from 9 to 441 mg/100 mL, with a mean of 165.8 ± 79.5 mg/100 mL. For pedestrians, the incidence of THC and ethanol in the blood was 7.6 and 53.3%, respectively.

The incidence of THC in the driver victims in this study constitutes an approximately threefold increase over the results of an Ontario study completed in 1979. At least a part of the increase may be attributed to interstudy differences in analytical methodology for cannabinoids.

KEYWORDS: toxicology, cannabis, ethanol, motor vehicle fatalities, traffic safety

The results of earlier research on the incidence between April 1978 and March 1979 of drugs in traffic fatalities occurring in the Province of Ontario, Canada, [*1*] clearly demonstrated that, next to ethanol, cannabis was the most frequently detected psychoactive drug found among the drivers studied. Considering that the toxicological methods employed in that study were designed to detect a wide variety of drugs, the cannabis findings were very interesting and, in fact, provided the main impetus for the present project. The purpose of this work was to monitor the use of cannabis, and incidentally of ethanol, in a much larger study sample than was previously used to evaluate any changes or trends in the pattern of cannabis use in this selected population.

Although the former [*1*] and the present studies constitute the only reported Canadian

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projects of this type, other drug incidence studies in traffic fatalities have been reported in the United States [2–7], Australia [8], and the United Kingdom [9].

Materials and Methods

In the 29-month period of this study (1 March 1982 to 31 July 1984), there were 2655 fatal motor vehicle crashes in Ontario, all of which were investigated under the authority of the Chief Coroner for the Province of Ontario. These crashes resulted in the deaths of 2114 persons 14 years old or older, and of these, 1394 met the predetermined criteria for inclusion in the study: that is, that the time of death was within 1 h of the collision (491 cases were excluded) and that adequate blood specimens were available (229 cases were excluded). This final study sample, comprising 1169 drivers and 225 pedestrians, was found to be generally representative of the total set of fatalities when the two groups were compared for the key variables of the region of Ontario, age, sex, collision type, and vehicle type.

The specimens used for the analyses of ethanol and cannabinoids were blood (collected whenever possible from intact vessels or chambers of the heart) and urine (if available). Both blood and urine specimens were submitted in approximately two thirds of the cases. All the specimens contained sodium fluoride and sodium citrate (approximately 1 and 0.5%, respectively) as an anticoagulant/preservative. The preserved specimens were typically received at the Centre of Forensic Sciences, Toronto, Ontario, within one to three days of autopsy and were kept refrigerated (at 5°C) until analyzed.

Ethanol was determined in blood and urine by a semiautomated, headspace gas chromatography (GC) method using tertiary butanol as the internal standard [10].

The cannabinoid analyses consisted of an initial screening of blood and urine by a series of radioimmunoassays (RIAs) and subsequent determination of delta-9-tetrahydrocannabinol (THC) in the blood by gas chromatography/mass spectrometry (GC/MS) when positive RIA screening test results exceeded preestablished values. The methods used were the following:

1. Blood was assayed for THC and for 11-nor-9-carboxy-delta-9-tetrahydrocannabinol (carboxy-THC) by RIA reagent kits obtained from the Research Triangle Institute (RTI)[4] through the courtesy of the U.S. National Institute on Drug Abuse (NIDA).[5] These kits were designed for use with hemolyzed blood and utilized ^{125}I-labeled antigens and solid-phase second antibodies for separation. The kits were evaluated at the Centre of Forensic Sciences and found to be very useful for screening purposes. When these tests indicated apparent THC values of 2 ng/mL or greater or apparent carboxy-THC values of 2.5 ng/mL or greater, the blood specimens were subsequently analyzed for THC by GC/MS.
2. The screening of urine specimens for cross-reacting cannabinoids was carried out with commercially produced RIA reagents,[6] which were also employed in the previous study cited [1]. Results of 12.5 ng/mL or greater were considered positive and were routinely followed by GC/MS analysis of the blood for THC.
3. The quantitative analysis of THC in the blood was carried out by a GC/MS procedure similar to that reported by Rosenthal and Brine [11]. In the present work, the modifications included the use of a capillary column (DB-5, 15 m by 0.25-mm inside diameter, 0.1-μL film thickness) and temperature programing (100 to 260°C, at 16°C per minute). The usual sensitivity of this procedure was found to be less than 1 ng/mL of THC in blood, although this limit was found to vary considerably

[4]RTI, P.O. Box 12194, Research Triangle Park, NC 27709.
[5]NIDA, Rockville, MD 20857.
[6]Collaborative Research Inc., 1365 Main St., Waltham, MA. The products are no longer commercially available.

depending on the biological matrix of a particular specimen. Only the GC/MS results for THC were used for the compilation of positive findings in blood.

Results

The overall incidence of THC and ethanol in the study sample comprised of 1169 drivers and 225 pedestrians is illustrated in Table 1. All data in this tabulation were derived from the analyses of blood. In drivers, the incidence of THC and ethanol was 10.9 and 57.1%, respectively; in pedestrians, the corresponding results were 7.6 and 53.3%, respectively. The vast majority of the THC-positive victims also had consumed alcoholic beverages; in drivers, only 20 of the 127 THC-positive victims had no detectable ethanol.

In addition to the victims with positive THC findings in their blood, there were 74 other driver fatalities and 9 other pedestrian fatalities in which the urine specimens were positive for cannabinoids; however, no THC was detectable in the corresponding blood specimens by GC/MS. These additional cases were most likely to have been victims who had used cannabis at some considerable length of time prior to the crash and for whom no behavioral impairment could therefore be expected of their driving ability at the time of the accident. Addition of these cases to the THC-positive victims results in a total incidence of cannabinoids (that is, of cannabis use) of 17.2% in drivers and 11.6% in pedestrians.

With respect to ethanol, its involvement not unexpectedly exceeded that of THC (Table 1). More than three times as many drivers had been drinking (57.1%) as had been using cannabis (17.2%). The blood ethanol concentrations (BECs) of the 667 drinking drivers ranged from 9 to 441 mg/100 mL, with a mean (± standard deviation) of 168.8 mg/100 mL (±79.5). The majority of these drivers were drinking considerably, with 84% having BECs greater than 80 mg/100 mL, the Canadian statutory limit for driving. For pedestrians, the BECs ranged from 6 to 357 mg/100 mL, with a mean of 184 mg/100 mL (±78.6).

A summary of the THC blood concentrations detected in the traffic victims is illustrated in Table 2. For drivers, the THC blood concentrations ranged between 0.2 and 37 ng/mL, with a mean of 3.1 ng/mL (±5.0) and a median of 1.6 ng/mL. For pedestrians, the range was from 0.6 to 7.9 ng/mL, with a mean of 2.4 ng/mL (±2.3) and a median of 1.5 ng/mL. In 6 of the drivers and in 1 of the pedestrians, the THC findings were expressed as "trace," which means that the values were near the detection limit of the method and difficult to quantitate accurately. The distribution of the blood THC concentrations found

TABLE 1—*Overall incidence of THC and ethanol in motor vehicle fatalities.*

Category	Number (%)	
	Drivers	Pedestrians
THC alone	20 (1.7)	4 (1.8)
Ethanol alone	560 (47.9)	107 (47.6)
THC and ethanol	107 (9.2)	13 (5.8)
No THC or ethanol	482 (41.2)	101 (44.9)
Totals		
THC incidence	127 (10.9)	17 (7.6)
Ethanol incidence	667 (57.1)	120 (53.3)
Study sample	1169	225

TABLE 2—*Summary of the THC blood concentrations in traffic fatality victims.*

Victims	THC Concentration, ng/mL	Number of Victims
Drivers	0.2 to 4.9	107
	5.0 to 9.9	14
	≥10.0	6
Range	0.2 to 37.0	127
Mean ± SD	3.1 ± 5.0	
Median	1.6	
Pedestrians	0.6 to 4.9	15
	5.0 to 9.9	2
	≥10.0	0
Range	0.6 to 7.9	17
Mean ± SD	2.4 ± 2.3	
Median	1.5	

in the traffic victims was markedly skewed toward the lower values, with 84% of the drivers (88% of the pedestrians) having THC blood concentrations of less than 5 ng/mL.

As illustrated in Table 1, only 20 of the 127 THC-positive drivers were ethanol-free. It is noteworthy that in this group of drivers, THC blood concentrations greater than 5 ng/mL were more frequent than in the entire set, resulting in a higher mean of 5.4 ng/mL. Interestingly enough, the mean BEC of the 107 drinking drivers who also had detectable THC was 151 mg/100 mL, a lower value than the one for all drinking drivers. Both these observations tend to support the anticipated mutual enhancement of pharmacological effects between the two drugs. This is also illustrated in Table 3, which shows a decrease in the incidence of THC as the magnitude of the BECs increased.

In addition to BEC, there were four other variables which influenced the frequency of THC occurrence among the traffic victims: these were age, sex, vehicle type, and the availability of the requested specimens.

The important roles of age and sex on the incidence of THC in driver victims are illustrated in Table 4. As can be observed, the presence of THC was much more prevalent in males than in females, with the incidence being 12.4 and 1.8%, respectively. In fact, all but 3 of the 127 THC-positive drivers were males. With respect to age, the THC-positive drivers were between 17 and 50 years old; however, those between 17 and 24 years had clearly the highest frequency of THC presence, with a noteworthy THC incidence of 22% for the males 17 to 24 years old. Drivers in this age group comprised 38% of all the drivers studied but contributed 72% of the THC-positive cases. Only 4

TABLE 3—*Incidence of THC in drinking driver fatalities as a function of BEC.*

Blood Ethanol Concentration, mg/100 mL	Number of Cases	THC Incidence, number (%)
9 to 79	107	20 (18.7)
80 to 149	164	27 (16.5)
≥150	396	60 (15.1)

TABLE 4—*Incidence of THC in driver fatalities as a function of age and sex.*

Sex	Age, years	Number of Cases	Incidence, %
Males	17 to 24	400	22.0
	≥25	599	6.0
	All	999	12.4
Females	17 to 24	47	6.4
	≥25	122	0
	All	169	1.8
All drivers		1169[a]	10.9

[a]The sex of one driver was unknown.

of the 127 THC-positive drivers were older than 35 years. For pedestrians, the general age pattern was qualitatively similar.

The effect of the availability of both blood and urine specimens on the incidence of THC detection was interesting to observe (Table 5), although somewhat difficult to explain satisfactorily. The significantly higher incidence of THC in the group of cases in which both blood and urine were analyzed can probably be partly attributed to the cannabinoid screening approach used and confirms the well-accepted usefulness of urine for screening drugs at low concentrations. However, since a similar specimen-related effect was also observed in the incidence of ethanol (both in drivers and in pedestrians), it is clear that factors other than methodology were also involved. One of these may well have been a decision by the pathologist to collect both specimens when positive toxicological findings were anticipated from observations at the autopsy.

Not surprisingly, drivers of motorcycles had a much higher incidence of THC use than drivers of the other types of vehicles (Table 6). The THC-positive motorcycle drivers were all males ranging in age from 19 to 50 years, with a mean (± standard deviation) of 23.3 years (±6.02). The THC blood concentrations ranged from 0.5 to 8.7 ng/mL, with a mean (± standard deviation) of 2.4 ng/mL (±2.0).

Discussion

Comparison of the results for ethanol and cannabinoids for the driver victims in the present study with those in the study completed in Ontario in 1979 [*1*] revealed a close similarity of the results for ethanol but an increase in the incidence of THC from 3.7 to

TABLE 5—*Incidence of THC as a function of specimen availability in traffic fatalities.*

Victims	Specimens Available	Number of Cases	Incidence, %
Drivers	blood	337	7.1
	blood and urine	832	12.4
	Total	1169	10.9
Pedestrians	blood	92	3.3
	blood and urine	133	10.5
	Total	225	7.6

TABLE 6—*Incidence of THC in driver fatalities as a function of vehicle type.*

Vehicle Type	Number of Cases	Incidence, number (%)
Automobile	728	65 (8.9)
Motorcycle/moped	192	43 (22.4)
Van/truck	139	8 (5.8)
Other[a]	110	11 (10.0)
All drivers	1169	127 (10.9)

[a]Includes mainly snowmobiles and tractor-trailers.

10.9% in the present study. The incidences of cannabinoids in the two studies were quite similar, that is, 12 and 12.7%, respectively. Although the approximately threefold increase observed in the incidence of THC in driver victims is very interesting, an accurate interpretation of this increase is difficult because of the differences between the two studies in cannabinoid methodologies as well as in specimen requirements. It is likely, however, that at least a part of the observed increase can be attributed to the interstudy differences.

It cannot be overemphasized that the detection of THC (or any other drug) in the blood of a driver victim does not necessarily signify contribution of the drug to the collision. However, the presence of THC in the blood may well be indicative of a relatively recent use of cannabis, and, therefore, the possibility of pharmacological effects of that drug at the time of the collision must be considered. It has been shown [*12*] that (hemolyzed) blood concentrations of THC are approximately half of those in the corresponding plasma specimens. In addition, THC blood concentrations detected by GC/MS could be considerably lower than those measured by RIA. These two factors must be taken into account when evaluating literature reports on the pharmacokinetics/pharmacodynamics of THC. As with other drugs acting on the central nervous system (with the exception of ethanol), it is very difficult to interpret the effects of a given blood drug concentration on driving ability, and unless extremely high values are obtained, only the possibility of adverse effects can be inferred on the basis of the blood drug findings alone. Although a more definitive opinion may be possible when all the relevant circumstances of a particular incident are known, such as opinion is then obviously not entirely toxicological in nature. Because of the number and complexity of the factors involved in the pharmacokinetics/pharmacodynamics of psychoactive drugs, particularly cannabis, it is not likely that a dramatic improvement in the toxicological interpretation capabilities in this area of work can be expected in the very near future.

Conclusions

The 57.1% incidence of ethanol found in the fatally injured drivers of this study is essentially unchanged from that of the previous study carried out in 1978 and 1979 in Ontario [*1*]. The incidence of THC, however, has increased approximately three times to 10.9%, although a part of this increase is probably due to interstudy differences in analytical methods.

Although ethanol incidence was much more extensive than that of cannabis, the incidence of THC, particularly in the category of young male drivers, is nevertheless noteworthy. The extent of the THC incidence, combined with the fact that, next to ethanol, cannabis was the drug detected most frequently in the fatally injured drivers

studied [*1,5,6,8,9*], provides sufficient grounds for concern and indicates the need for additional research to define further the significance of cannabis in traffic safety.

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