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Incidence and Toxicological Aspects of Drugs Detected in 484 Fatally Injured Drivers and Pedestrians in Ontario

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ABSTRACT: Results are presented of a comprehensive drug study carried out on specimens from drivers and pedestrians fatally injured in Ontario. Toxicological analyses were regularly performed on blood and urine and occasionally on vitreous humor, stomach contents, and liver. The analytical procedures could detect and quantitate a wide variety of drugs including such illicit drugs as *Cannabis.* With respect to drivers, alcohol was found in 57% of the study sample and drugs other than alcohol, in 26%. However, in only 9.5% of the drivers were psychoactive drugs (other than alcohol) detected in the blood in concentrations that may adversely affect driving skills. Δ-9-Tetrahydrocannabinol and diazepam accounted for a majority of the findings in this category.

KEYWORDS: toxicology, driving, traffic safety

It is generally recognized that many drugs can impair driving ability and thus potentially contribute to accidents. However, data on the involvement of drugs in individuals involved in collisions are not readily available. No such studies of traffic fatalities have been reported from Canada, and only a few reports have been published from the United States [*1-3*].

The present study supplements existing knowledge on this subject by investigating an adequate sample of traffic victims and by using a comprehensive toxicological screening approach designed to detect a wide variety of drugs, including such illicit drugs as *Cannabis.* It was hoped that the results of this work would provide baseline data and indicate the direction of future research in the field of drugs and traffic safety.

Materials and Methods

All drivers (768) and pedestrians (263) fatally injured in traffic accidents in the Province of Ontario between April 1978 and March 1979 were investigated. Of these 1031 victims, only

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401 drivers and 83 pedestrians met the criteria for inclusion in the study. Excluded were children younger than 14 years (71 cases), victims who died more than 1 h after admission to the hospital (159), victims from whom both blood and urine specimens were not available (302), and those from whom the specimens submitted were otherwise inadequate (15).

At autopsy, blood samples were collected whenever possible from intact vessels or chambers of the heart. Vitreous humor was removed from both eyes and combined. Specimens for alcohol analyses contained sodium fluoride and sodium citrate (approximately 1 and 0.5%, respectively) as anticoagulant/preservative.

Toxicological analyses were regularly carried out on blood and urine and occasionally on vitreous humor, stomach contents, and liver. Six screening procedures were uniformly applied to specimens from each case:

1. Alcohol was determined in blood, urine, and vitreous humor by a semiautomated, headspace, gas-chromatographic (GLC) method using tertiary butanol as internal standard for simultaneous quantitation [*4*].

2. Barbiturates were detected and quantitated in blood by the combination of ultraviolet (UV) differential and GLC techniques [*5*] having a detection limit of 1.5 mg/L.

3. Basic and neutral drugs were screened in 2 mL of blood and urine by a semiautomated, GLC procedure using nitrogen/phosphorus detectors [*6, 7*] with an average detection limit of approximately 0.2 mg/L.

4. Basic, neutral, and acidic drugs were analyzed in 30 mL of urine by the initial separation of the respective fractions and the application of standard UV and thin-layer chromatographic (TLC) techniques [*8*]. In addition, color tests for salicylate, bromide, and trichlorocompounds [*8*], phenothiazines [*9*], acetaminophen [*10*], ethchlorvynol [*11*], and imipramine [*12*] were regularly applied directly to the urine.

5. Chlordiazepoxide and oxazepam were screened in blood by a method utilizing the Bratton-Marshal reaction [*13*] and having a detection limit of 0.5 mg/L.

6. Morphine[4] (and cross-reacting narcotic analgesics), benzoylecgonine,[4] lysergic acid diethylamide (LSD),[5] and cannabinoids[5] were screened in urine and vitreous humor by commercially available radioimmunoassay (RIA) procedures.

The detection limits ("cutoff" concentrations) were as follows:

(a) morphine, codeine—0.04 mg/L,
(b) benzoylecgonine—0.1 mg/L,
(c) LSD—0.001 mg/L, and
(d) cannabinoids (expressed as Δ^9-tetrahydrocannabinol [THC]—0.012 mg/L.

Drugs (other than alcohol and cannabinoids) were quantitated in blood and liver tissue. Positive cannabinoid findings in urine were followed by the determination of THC in blood by a GLC/mass spectrometric (GLC/MS) procedure similar to that reported by Rosenthal and Brine [*14*]. Basic and neutral drugs were usually quantitated by GLC (flame ionization, electron capture, or nitrogen/phosphorus detectors) using co-extracted aqueous standards for calculation of results. Salicylate was estimated by a UV procedure [*15*], and acetaminophen [*16*], chlordiazepoxide, and oxazepam [*17*] were quantitated by high pressure liquid chromatography (HPLC). When required, further identification of drugs was accomplished by GLC/MS (Hewlett-Packard, Model HP5980A mass spectrometer).

[4]Abuscreen, Roche Diagnostics, Division of Hoffmann-LaRoche, Inc., Nutley, NJ.
[5]Collaborative Research Inc., 1365 Main Street, Waltham, MA. The sale of these products has since been discontinued.

Results and Discussion

The overall incidence of alcohol and drugs in the study sample comprising 484 traffic victims is illustrated in Fig. 1. The data were derived from all drug findings (other than caffeine and nicotine) obtained from blood or other body samples. Drugs were detected in 26% and alcohol (ethyl) in 57% of the drivers. In only 31% of the drivers could neither alcohol or drugs be detected.

Alcohol was the most frequent finding, having been detected in drivers with more than twice the frequency of all the other drugs combined. The blood alcohol concentrations (BAC) of the 269 drivers and pedestrians ranged between 80 and 4360 mg/L. In drivers, the mean BAC was 1630 mg/L and in pedestrians, 1450 mg/L. Forty-nine percent of all drivers (85.8% of the drinking drivers) had a BAC in excess of 800 mg/L, the Canadian statutory limit with respect to driving. The correlation of the alcohol concentrations in blood, urine, and vitreous humor specimens of these traffic victims will be the subject of a separate report.[6]

The frequencies of detection of drugs (other than alcohol) found in blood or other body samples are given in Table 1. Although 34 different drugs were detected (assuming that

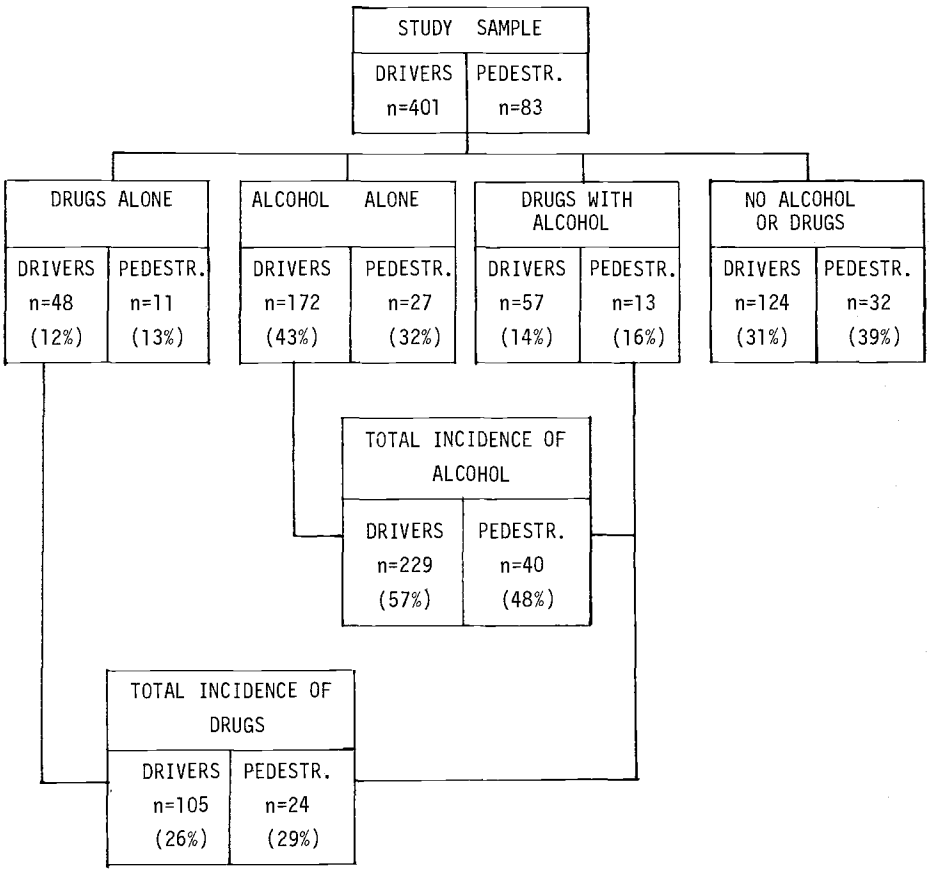

FIG. 1—*Overall incidence of ethyl alcohol and drugs in traffic victims (percent of study sample in parentheses).*

[6]Presented at the 33rd Annual Meeting of the American Academy of Forensic Sciences, Los Angeles, 1981.

TABLE 1—*Incidence of individual drugs.*

Drug	Number of Detections		% of Study Sample		% of Drug-Positive Sample	
	Drivers, $n = 401$	Pedestrians, $n = 83$	Drivers, $n = 401$	Pedestrians $n = 83$	Drivers, $n = 105$	Pedestrians, $n = 24$
Cannabinoids and metabolites	48	11	12.0	13.2	45.7	45.8
Salicylate	26	6	6.5	7.2	24.8	25.0
THC	15	1	3.7	1.2	14.2	4.2
Diazepam	12	4	3.0	4.8	11.4	16.6
Nordiazepam	9	4	2.2	4.8	8.6	16.6
Codeine	7	1	1.7	1.2	6.6	4.2
Acetaminophen	5	0	1.2	...	4.8	...
Diphenhydramine	3	0	0.7	...	2.9	...
Amitriptyline	2	1	0.5	1.2	1.9	4.2
Brompheniramine	2	1	0.5	1.2	1.9	4.2
Dextromethorphan	2	0	0.5	...	1.9	...
LSD metabolites	2	0	0.5	...	1.9	...
Oxazepam	2	0	0.5	...	1.9	...
Pheniramine	2	0	0.5	...	1.9	...
Trifluoperazine	2	0	0.5	...	1.9	...
Acetone	1	0	0.2	...	1.0	...
Benzoylecgonine	1	0	0.2	...	1.0	...
Benztropine	1	0	0.2	...	1.0	...
Chlordiazepoxide	1	0	0.2	...	1.0	...
Diethylpropion metabolite	1	0	0.2	...	1.0	...
Diphenylpyraline	1	0	0.2	...	1.0	...
Diphenylhydantoin	1	2	0.2	2.4	1.0	8.3
Hydrocodone	1	0	0.2	...	1.0	...
Maprotiline	1	0	0.2	...	1.0	...
Meprobamate	1	0	0.2	...	1.0	...
Methaqualone	1	0	0.2	...	1.0	...
Phenindamine	1	0	0.2	...	1.0	...
Propoxyphene	1	0	0.2	...	1.0	...
Propanolol	1	0	0.2	...	1.0	...
Protriptyline	1	0	0.2	...	1.0	...
Quinine	1	0	0.2	...	1.0	...
Theophylline	1	0	0.2	...	1.0	...
Doxepin	0	1	...	1.2	...	4.2
Naproxen	0	1	...	1.2	...	4.2
Phenobarbital	0	4	...	4.8	...	16.3
Primaclone	0	1	...	1.2	...	4.2
Total	156	38	...	...	...	...

nordiazepam findings were the result of diazepam administration), only 15 were found in more than one victim. It is interesting to note that the two most frequently detected psychoactive drugs were THC and diazepam in the driver fatalities and diazepam and phenobarbital in the pedestrians.

The total number of detections (194) exceeds the number of drug-positive victims (129) because of metabolite and multiple drug findings. The latter, however, were infrequent: 81.4% of the drug-positive victims had only one drug (Table 2).

The results of toxicological examinations of the 61 driver and 13 pedestrian victims in whom drugs were detected in the blood or liver tissue are shown in Tables 3 and 4. In these compilations (as well as in the subsequent tables), concentrations designated as "trace" are 0.001 to 0.002 mg/L for THC; 50 to 200 mg/L for ethyl alcohol; less than 10 mg/L or kg for salicylate; and typically less than 0.05 mg/L or kg for the other drugs. Liver concentrations

TABLE 2—*Number of drugs per case.*

Number of Drugs[a,b] Per Case	Number of Cases	Frequency, %
1	105	81.4
2	17	13.1
3	3	2.3
4	3	2.3
5	1	0.8

[a]Excluding ethanol.
[b]Excluding metabolites when detected with the parent drug.

TABLE 3—*Toxicological data for drivers.*

Case	Age/Sex	Drugs	Concentration in Blood, mg/L	Concentration in Liver, mg/kg	Impairment Rating, Drugs[a]
1	18/m	THC	0.002	na[b]	1
		ethanol	200	na	
2	18/m	THC	0.005	na	1
3	17/m	THC	trace	na	1
		ethanol	1560	na	
4	21/m	THC	trace	na	1
		ethanol	750	na	
5	22/m	THC	0.002	na	1
		ethanol	2730	na	
6	20/m	THC	0.005	na	1
		ethanol	2360	na	
7	29/m	THC	trace	na	1
		ethanol	830	na	
8	16/m	THC	trace	na	1
		ethanol	390	na	
9	19/m	THC	0.002	na	1
		ethanol	1710	na	
10	21/m	THC	0.002	na	1
		ethanol	2710	na	
11	21/m	THC	trace	na	1
		ethanol	2190		
12	18/m	THC	trace	na	1
		ethanol	3120	na	
13	20/f	THC	trace	na	1
		diphenhydramine	trace	0.20	
		codeine	trace	negative	
14	24/m	THC	trace	na	1
		ethanol	360	na	
15	19/m	THC	trace	na	1
		ethanol	1060	na	
16	71/m	diazepam	0.10	0.26	1
		nordiazepam	0.10	0.34	
17	56/m	diazepam	0.30	1.3	2
		nordiazepam	negative	1.6	
		ethanol	1860	na	
18	78/m	diazepam	0.35	trace	2
19	39/f	diazepam	0.40	na	2
		nordiazepam	trace	na	
		ethanol	1650	na	

TABLE 3—(con.)

Case	Age/Sex	Drugs	Concentration in Blood, mg/L	Concentration in Liver, mg/kg	Impairment Rating, Drugs[a]
20	34/m	diazepam	0.07	negative	1
		ethanol	2010	na	
21	65/m	diazepam	0.06	trace	2
		nordiazepam	0.09	0.30	
		maprotiline	0.20	0.60	
22	79/m	diazepam	trace	trace	1
		salicylate	20	15	
23	49/f	diazepam	0.20	na	1
		nordiazepam	0.40	na	
		brompheniramine	trace	na	
		codeine	trace	na	
		acetaminophen	trace	na	
24	26/f	diazepam	trace	trace	1
		diphenylhydantoin	0.40	7.3	
25	32/m	diazepam	0.30	0.15	2
		ethanol	1030	na	
26	40/m	diazepam	0.10	na	1
27	22/m	diazepam	0.40	0.30	2
		nordiazepam	negative	0.30	
		ethanol	1750	na	
28	26/f	trifluoperazine	negative	0.26	0
29	41/f	amitriptyline	trace	4.0	1
		salicylate	20	negative	
30	42/m	amitriptyline	0.30	na	2
31	26/m	benzoylecgonine	trace	na	1
		ethanol	2160	na	
32	46/m	protriptyline	trace	6.0	1
33	31/m	oxazapem	0.30	trace	1
		trifluoperazine[c]	negative	negative	
		benztropine[c]	negative	negative	
34	26/m	phenindamine	trace	3.4	0
		salicylate	92	64	
		ethanol	560	na	
35	24/m	quinine	0.80	3.2	0
		ethanol	1630	na	
36	50/m	chlordiazepoxide	1.0	negative	1
		ethanol	2240	na	
37	47/m	methaqualone	3.0	3.0	2
		salicylate[c]	negative	negative	
38	62/m	propranolol	0.30	1.3	1
		ethanol	trace	na	
39	61/m	dextromethorphan	0.15	1.0	2
		diphenhydramine	negative	trace	
		ethanol	1620	na	
40	26/m	dextromethorphan	2.9	18.4	2
		pheniramine	0.65	3.1	
41	22/f	brompheniramine	negative	trace	0
		salicylate[c]	negative	negative	
		codeine[c]	negative	negative	
42	65/m	propoxyphene	trace	0.90	0
		ethanol	2770	na	
43	74/m	meprobamate	6.0	na	1
		theophylline	4.0	na	
		codeine	trace	na	
		salicylate[c]	negative	negative	
44	25/m	salicylate	20	na	0
45	15/m	salicylate	30	na	0

TABLE 3—(con.)

Case	Age/Sex	Drugs	Concentration in Blood, mg/L	Concentration in Liver, mg/kg	Impairment Rating, Drugs[a]
46	47/m	salicylate	50	40	0
		ethanol	830	na	
47	21/m	salicylate	10	negative	0
		lidocaine[d]	positive	na	
		ethanol	450	na	
48	15/m	salicylate	15	na	0
49	20/f	salicylate	27	trace	0
		ethanol	1340	na	
50	56/m	salicylate	15	negative	0
		acetaminophen	18	negative	
51	29/f	salicylate	45	35	0
52	69/m	salicylate	20	negative	0
		codeine[c]	negative	negative	
53	66/m	salicylate	25	trace	0
54	33/m	salicylate	10	trace	0
55	17/m	salicylate	20	negative	0
56	52/m	salicylate	trace	negative	0
57	16/m	salicylate	25	15	0
58	29/m	salicylate	15	negative	0
59	24/m	acetaminophen	12	na	0
		ethanol	1270	na	
60	35/f	acetaminophen	9	26	0
61	39/m	acetaminophen	15	na	0
		ethanol	880	na	

[a]Rating is an estimate with respect to adverse effect of drug(s) on driving ability and excludes the role of ethanol when present: 0 = no adverse effects expected; 1 = adverse effects possible; 2 = adverse effects likely.
[b]na = not analyzed.
[c]Positive in urine.
[d]Resuscitative administration.

were determined for all drugs other than THC to obtain blood and liver correlation data. Such information is not readily available for this type of case and is occasionally useful in practice. As expected, the liver concentrations of basic drugs, in most instances, were higher than the corresponding levels in blood. On the other hand, salicylate concentrations were usually lower in the liver tissue.

The THC blood concentrations in the 16 victims (Tables 3 and 4) ranged between trace and 0.005 mg/L. Considering that the drug was determined in hemolyzed whole blood (plasma THC levels would be expected to be higher), these THC blood concentrations in the traffic victims are consistent with low to moderate doses of *Cannabis* (5 to 15 mg THC) smoked within several hours of the fatal accident [*18,19*]. Since the pharmacological effects from smoking *Cannabis* may last 2 or 3 h [*20*], the possibility that the THC blood concentrations detected in the drivers adversely affected their ability to drive safely must be considered. It should be noted that 14 of the 16 THC-positive victims also had consumed alcohol and had BACs between trace and 3120 mg/L, with an average of 1433.5 mg/L. Drugs other than alcohol were found in only one case (Case 13), and THC alone also in one case (2). All but one of the THC-positive victims were males, and all were young, ranging in age between 17 and 29 years (average, 20 years).

Diazepam blood concentrations of the 16 victims listed in Tables 3 and 4 ranged between trace and 0.40 mg/L. A recent review of research on the effects of diazepam on driving-related skills [*21*] has shown that therapeutic doses of this drug can impair human perfor-

TABLE 4—*Toxicological data for pedestrians.*

Case	Age/Sex	Drugs	Concentration in Blood, mg/L	Concentration in Liver, mg/kg
62	20/m	THC	0.003	na[a]
		ethanol	trace	na
63	15/m	diazepam	0.30	1.5
		ethanol	1160	na
64	69/m	diazepam	0.10	0.40
		nordiazepam	0.20	1.5
		salicylate	25	trace
		ethanol	1830	na
65	53/f	diazepam	trace	1.3
		nordiazepam	negative	1.4
		amitriptyline	trace	3.9
		doxepin	trace	1.2
		codeine	trace	negative
		salicylate	45	25
		ethanol	860	na
66	37/m	diazepam	trace	trace
		nordiazepam	0.30	1.9
		ethanol	4360	na
67	27/f	phenobarbital	25.0	na
		diphenylhydantoin	1.3	na
68	19/m	phenobarbital	7.0	na
69	34/f	phenobarbital	15.0	12.0
		primaclone	7.0	trace
70	27/m	phenobarbital	18.0	10.0
		diphenylhydantoin	6.4	4.6
71	31/m	brompheniramine	negative	0.50
		salicylate[b]	negative	negative
72	19/m	salicylate	20	trace
		ethanol	290	na
73	53/m	salciylate	20	trace
74	72/m	salicylate	25	trace

[a]na = not analyzed.
[b]Positive in urine.

mance. In seven of the drivers (Table 3), the blood diazepam concentrations are consistent with normal therapeutic doses (Cases 16, 20, 21, 22, 23, 24, and 26). In the remaining five drivers (Cases 17, 18, 19, 25, and 27), the higher blood diazepam concentrations and the absence (or low level) of its metabolite in the blood suggest larger doses not taken chronically. Under these conditions, the victims would be more prone to exhibit the impairing effects of this drug [*22*]. In 9 of the 16 cases (Tables 3 and 4), diazepam was combined with alcohol (average BAC of 1834.4 mg/L) and, in six cases, with therapeutic blood concentrations of other drugs. Diazepam alone was found in three drivers. In contrast to the *Cannabis* users, the average age of the 16 diazepam-positive victims was 53 years (range between 15 and 79).

Other psychoactive drugs were detected with much lower frequency. In one driver (Case 30), the blood concentration of amitriptyline is a little above the normal therapeutic range [*23*] and could be expected to cause impairment [*24*]. Similarly, the blood concentration of propranolol (Case 38) is slightly above the normal therapeutic range [*25*]. Results of a recent study of the effect of propranolol on human psychomotor function indicate that when acutely administered, single doses of this drug can result in some decrease in performance [*26*]. Worthy of note are the two drivers (Cases 39 and 40) in whom dextromethorphan was detected. While this drug would not likely cause impairment when used in therapeutic doses,

the blood concentrations found in both these drivers are grossly elevated [*27*] and indicate an abuse of this drug. In view of this, adverse effects related to depressed central nervous system function could be expected [*28*]. The remaining drugs shown in Tables 2 and 3 were detected in therapeutic blood concentrations.

Not listed in Tables 2 and 3 are traffic victims in whom drugs were detected only in the urine, and a majority of these case (43 victims) involve findings of cannabinoid metabolites. While these findings identify the victims as previous *Cannabis* users, no behavioral impairment at the time of their accident would be expected because there were no detectable levels of THC in the blood. In two other cases (both young drivers) the presence of LSD metabolite was indicated in the urine.

As mentioned earlier, 547 cases were excluded from the drug incidence study. Many of these, however, were subjected to toxicological examination, and the results obtained in selected cases are given in Table 5 for the drivers and Table 6 for the pedestrians. In several of these victims (Cases 5, 16, 18, 25, 26, and 27) the drugs found were the result of administrations in the hospital after the accident; these are given for their toxicological interest only.

In Table 5, both cases in which THC was detected (Cases 1 and 2) are noteworthy. In the first, the THC blood concentration of 0.035 mg/L is the highest found in this work. Several joints were found in the car, one of which was only partially smoked. It is possible that the driver was smoking just before the crash. The second case involved a driver who survived for about 4 h after accident. In view of this, the THC blood concentration at the time of the collision could have been considerably higher [*18,19*]. Also of special interest is Case 15 since it represents the only amphetamine occurrence in this study. The amphetamine blood concentration in this victim is above the normal therapeutic range [*29*] and, in a study by Bonnischsen et al [*30*], was associated with a driver considered to be under the influence of this drug.

To evaluate the suitability of vitreous humor for the analysis of cannabinoids, that specimen was screened by RIA in 34 cases in which cannabinoids were detected, 9 of which had detectable THC concentrations in the blood (trace to 0.005 mg/L). All analyses of the vitreous humor gave negative results. This was somewhat surprising since the RIA employed for the analyses is capable of detecting not only THC but also its major metabolite, 11-nor-9-carboxy-THC [*31*]. While the THC blood concentrations in the cases studied are below the detection limit of the RIA, the corresponding blood concentrations of the carboxy metabolite would be expected to be significantly higher and persist in the blood for a longer period of time [*32*]. Although further work is required before definite conclusions can be reached, the results of this limited study indicate that vitreous humor is not a suitable specimen for the screening of cannabinoids.

Conclusions

The data obtained in this study are believed to reflect the true incidence of drug involvement in drivers and pedestrians killed in traffic accidents in Ontario. Although the study sample (484 victims) represents only 47% of the total number of victims (1031), an assessment of the excluded category led to the conclusion that whatever discrepancies may have been between the two groups were unlikely to be sufficient to bias the results significantly.

Not unexpectedly, alcohol dominates all the other drugs found in this study. More than twice as many drivers (57%) had been using alcohol than all other drugs combined (26%), and most of the drinking drivers (85.8%) had a BAC exceeding the Canadian statuatory limit of 800 mg/L. Undoubtedly, alcohol is the major drug problem with respect to traffic safety.

Drugs other than alcohol were found in 26% of the fatally injured drivers and 29% of the killed pedestrians. However, in only 9.5% of the drivers (38 cases) were psychoactive drugs detected in the blood in concentrations that may adversely affect driving skills. THC (15

TABLE 5—*Toxicological data for selected drivers excluded from incidence study.*

Case	Age/Sex	Drugs	Concentration in Blood mg/L	Concentration in Liver mg/kg	Reason for Exclusion
1	23/m	THC	0.035	na[a]	urine not available
		ethanol	1600	na	
2	29/f	THC	trace	na	died more than 1 h after admission
3	56/f	diazepam	0.07	negative	urine not available
		nordiazepam	0.04	negative	
		chlorpheniramine	trace	1.5	
		amitriptyline	trace	trace	
		chlordiazepoxide	neg	trace	
4	21/f	diazepam	trace	trace	urine not available
		nordiazepam	trace	trace	
		ethanol	1600	na	
5	36/m	diazepam	trace	trace	drug given in hospital
6	34/m	diazepam	0.07	negative	died more than 1 h after admission
		ethanol	2010	na	
7	47/m	diazepam	0.10	0.30	died more than 1 h after admission
		amitriptyline	0.20	11.0	
8	50/m	chlordiazepoxide	0.16	na	urine not available
9	32/m	chlordiazepoxide	1.4	2.4	urine not available
		ethanol	1700	na	
10	40/m	chlordiazepoxide	1.1	3.7	urine not available
		ethanol	1670	na	
11	23/m	chlordiazepoxide	1.0	3.0	died more than 1 h after admission
		acetone	40	na	
		isopropanol	50	na	
		ethanol	1230	na	
		cannabinoids[b]	negative	na	
12	60/f	amitriptyline	trace	negative	urine not available
		ethanol	1390	na	
13	51/m	propoxyphene	0.20	1.3	urine not available
		salicylate	10	trace	
14	27/m	meprobamate	14.0	84.0	urine not available
		ethanol	2090	na	
15	60/f	amphetamine	0.20	0.40	urine not available
16	20/m	meperidine	0.80	0.30	meperidine and lidocaine given in hospital
		lidocaine	1.4	0.20	
		ethanol	trace	na	died more than 1 h after admission
		cannabinoids[b]	negative	negative	
17	23/f	barbiturate	2.0	2.0	urine not available
18	23/m	nikethamide	90.0	trace	nikethamide given in hospital; died more than 1 h after admission
		ethanol	1650	...	
19	43/m	trimipramine	0.48	na	urine not available
		ethanol	580	na	

[a]na = not analyzed.
[b]Positive in urine.

TABLE 6—*Toxicological data for selected pedestrians excluded from incidence study.*

Case	Age/Sex	Drugs	Concentration in Blood mg/L	Concentration in Liver mg/kg	Reason for Exclusion
20	34/m	THC	trace	na[a]	urine not available
		ethanol	1650	na	
21	18/m	diazepam	0.10	na	urine not available
22	75/m	chlordiazepoxide	0.80	2.7	urine not available
		ethanol	1360	na	
23	71/f	oxazepam	0.60	na	urine not available
24	26/m	amobarbital-secobarbital	5.5[b]	16.0[b]	urine not available
		ethanol	1470	na	
25	76/f	meperidine	0.19	0.35	drugs given, in hospital
		lidocaine	0.78	0.20	
26	58/f	meperidine	0.80	0.90	given in hospital
27	62/m	morphine	trace	negative	given in hospital

[a]na = analyzed.
[b]Total barbiturate concentration.

cases) and diazepam (12 cases) accounted for a majority (67.5%) of the findings in this category. THC was typically found (13 of the 15 cases) together with alcohol.

The 9.5% incidence of potentially significant drug findings is not alarming but is of sufficient concern that drugs may represent a threat to traffic safety. Of greatest concern are *Cannabis* and diazepam, and the results of this study clearly indicate that these two drugs warrant priority for future traffic safety research.

Finally, it must be clearly recognized that detection of any drug does not necessarily imply contribution of that drug to the collision. Such inferences could only be advanced after consideration of the circumstances of the crash as well as information on drug use in the population at risk. This information is not yet available.

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References

[1] Woodhouse, E. J., "The Incidence of Drugs in Fatally Injured Drivers," Midwest Research Institute Report PB-230948, Kansas City, MO, Feb. 1974.

[2] Turk, R. F., McBay, A. J., and Hudson, P., "Drug Involvement in Automobile Driver and Pedestrian Fatalities," *Journal of Forensic Sciences*, Vol. 19, No. 1, Jan. 1974, pp. 90-97.

[3] Garriott, J. C., DiMaio, V. J. M., Zumwalt, R. E., and Petty, C. S., "Incidence of Drugs and Alcohol in Fatally Injured Motor Vehicle Drivers," *Journal of Forensic Sciences*, Vol. 22, No. 2, April 1977, pp. 383-389.

[4] Machata, G., "Determination of Alcohol in Blood by Gas Chromatographic Headspace Analysis," *Clinical Chemistry Newsletter*, Vol. 4, No. 2, Winter 1972, pp. 29-32.

[5] Yen, B. and Cimbura, G., "Comparison of the UV Differential and the GLC Methods for the Quantitation of Barbituates in Blood," *Canadian Society of Forensic Science Journal,* Vol. 9, No. 3, Sept. 1976, pp. 113-116.

[6] Wells, J., Cimbura, G., and Koves, E., "The Screening of Blood by Gas Chromatography for Basic and Neutral Drugs," *Journal of Forensic Sciences,* Vol. 20, No. 2, April 1975, pp. 382-390.

[7] Wells, J. and Cimbura, G., "Street Drugs and the Forensic Toxicologist," *Proceedings of the International Symposium on Instrumental Applications in Forensic Drug Chemistry,* U.S. Government Printing Office, Washington, DC, 1978, pp. 214-220.

[8] Clarke, E. G. C., *Isolation and Identification of Drugs,* Vol. 1, The Pharmaceutical Press, London, 1969.

[9] Lucas, G. H. W. and Fabierkiewicz, C., "Useful Tests to Identify Phenothiazine Tranquilizers," *Journal of Forensic Sciences,* Vol. 8, No. 3, July 1963, pp. 462-476.

[10] Simpson, E. and Stewart, M. J., "Screening for Paracetamol Poisoning," *Annals of Clinical Biochemistry,* Vol. 10, 1973, pp. 171-172.

[11] Finkle, B. S. and Bath, R., in *Methodology for Analytical Toxicology,* I. Sunshine, Ed., C.R.C. Press, Cleveland, 1975, p. 155.

[12] Cimbura, G., in *Methodology for Analytical Toxicology,* I. Sunshine, Ed., C.R.C. Press, Cleveland, 1975, p. 192.

[13] Kananen, G., in *Methodology for Analytical Toxicology,* I. Sunshine, Ed., C.R.C. Press, Cleveland, 1975, pp. 75-76.

[14] Rosenthal, D. and Brine, D., "Quantitative Determination of Delta-9-Tetrahydrocannabinol in Cadaver Blood," *Journal of Forensic Sciences,* Vol. 24, No. 2, April 1979, pp. 282-290.

[15] Williams, L. A., Linn, R. A., and Zak, B., "Differential UV Spectrophotometric Determination of Serum Salicylates," *Journal of Laboratory and Clinical Medicine,* Vol. 53, No. 1, Jan. 1959, pp. 156-162.

[16] Morwitz, R. A. and Jatlow, P. I., "Determination of Acetaminophen in Serum by High Pressure Liquid Chromatography," *Clinical Chemistry,* Vol. 23, No. 9, Sept. 1977, pp. 1596-1598.

[17] Peat, M. A. and Kopjak, L., "The Screening and Quantitation of Diazepam, Flurazepam, Chlordiazepoxide and Their Metabolites in Blood and Plasma by Electron-Capture Gas Chromatography and High Pressure Liquid Chromatography," *Journal of Forensic Sciences,* Vol. 24, No. 1, Jan. 1979, pp. 46-54.

[18] Willett, R. E., Ed., *Cannabinoid Assays in Humans,* Research Monograph 7, National Institute on Drug Abuse, Rockville, MD, 1976.

[19] Owen, S. M., McBay, A. J., Reisner, H. M., and Perez-Reyes, M., "^{125}I Radioimmunoassay of Delta-9-Tetrahydrocannabinol in Blood and Plasma with a Solid-Phase Second-Antibody Separation Method," *Clinical Chemistry,* Vol. 27, No. 4, April 1981, pp. 619-624.

[20] Goodman, L. S. and Gilman, A., *The Pharmacological Basis of Therapeutics,* 6th ed., MacMillan Publishing Co., Inc., New York, 1980, p. 562.

[21] Speaker, J. H., "General Tranquilizers," in *Drugs and Driving,* R. E. Willett, Ed., Research Monograph 11, National Institute on Drug Abuse, Rockville, MD, 1978, pp. 39-43.

[22] Hillestad, L., Hansen, T., and Melsom, H., "Diazepam Metabolism in Normal Man," *Clinical Pharmacology and Therapeutics,* Vol. 16, No. 3, Sept. 1974, pp. 479-484.

[23] Baselt, R. C., *Disposition of Toxic Drugs and Chemicals in Man,* Vol. 1, Biomedical Publications, Canton, CT, 1978, p. 170.

[24] Bye, C., Chubley, M., and Peck, A. W., "Drowsiness, Impaired Performance and Tricyclic Antidepressant Drugs," *British Journal of Clinical Pharmacology,* Vol. 6, No. 2, Aug. 1978, pp. 155-161.

[25] Baselt, R. C., *Disposition of Toxic Drugs and Chemicals in Man,* Vol. 2, Biomedical Publications, Canton, CT, 1978, p. 31.

[26] Broadhurst, A. D., "The Effect of Propanolol on Human Psychomotor Performance," *Aviation, Space, and Environmental Medicine,* Vol. 51, No. 2, Feb. 1980, pp. 176-179.

[27] Barnhart, J. W. and Massad, E. N., "Determination of Dextromethorphan in Serum by Gas Chromatography," *Journal of Chromatography,* Vol. 163, 1979, pp. 390-395.

[28] Goodman, L. S. and Gilman, A., *The Pharmacological Basis of Therapeutics,* 6th ed., MacMillan Publishing Co., Inc., New York, 1980, p. 529.

[29] Baselt, R. C., *Disposition of Toxic Drugs and Chemicals in Man,* Vol. 1, Biomedical Publications, Canton, CT, 1978, p. 189.

[30] Bonnischsen, R., Maehly, A. C., Marde, Y., Ryhage, R., and Schubert, B., "Determination and Identification of Sympathomimetic Amines in Blood Samples from Drivers by a Combination of Gas Chromatography and Mass Spectrometry," *Journal of Legal Medicine,* Vol. 67, 1970, pp. 19-26.

[31] Chase, A. R., Kelley, P. R., Taunton-Rigby, A., Jones, R. T., and Harwood, T., "Quantitation of Cannabinoids in Biological Fluids by Radiommunoassay," in *Cannabinoid Assays in Humans,* R.

E. Willett, Ed., Research Monograph 7, National Institute on Drug Abuse, Rockville, MD, 1976, pp. 1-9.

[32] Gross, S. J. and Soares, J. R., "Separate Radioimmune Measurements of Body Fluid Delta-9-THC and 11-nor-9-carboxy-9-THC," in *Cannabinoid Assays in Humans,* R. E. Willett, Ed., Research Monograph 7, National Institute on Drug Abuse, Rockville, MD, 1976, pp. 10-14.

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