Pergamon

Accid. Anal. and Prev., Vol. 29, No. 6, pp. 817–827, 1997

0001-4575/97 $17.00 + 0.00

PII: S0001-4575(97)00051-1

CRASH CHARACTERISTICS AND INJURIES OF VICTIMS IMPAIRED BY ALCOHOL VERSUS ILLICIT DRUGS[1]

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(Received 16 October 1995)

Abstract—Alcohol has long been associated with injury, but the relationship between other drugs and injury is less clear. Blood samples from 894 patients presenting to two Emergency Departments for treatment of motor vehicle injury sustained in passenger cars, station wagons, vans and pickup trucks, were tested for alcohol and other drugs. Results were related to demographic characteristics, including prior history of alcohol and drug use; crash characteristics; and injury characteristics. Alcohol was associated with more severe crashes, but other drugs, in the absence of alcohol, were not. The crashes involving drugs but no alcohol were very similar to those involving neither alcohol nor drugs. © 1997 Elsevier Science Ltd.

Keywords—Alcohol, Crashes, Drugs, Injury

INTRODUCTION

It has long been known that alcohol is associated with risk of injury, and there are numerous reports documenting this relationship (Cherpitel, 1993). Furthermore, we know that alcohol increases the probability of motor vehicle injury in at least four ways. First, it impairs judgment and hence increases the probability that one will engage in high risk behavior that may lead to injury. Second, it impairs psychomotor performance so that once a crisis situation arises, the response may not be adequate or appropriate so that injury may result. Third, there is growing evidence that alcohol increases the amount of injury sustained from a given traumatic impact (Anderson, 1986; Waller et al., 1986a,b, 1989). Finally, long-term use of alcohol can increase bone fragility, thus increasing vulnerability to injury (Hernandez-Avila et al., 1991); and alcohol can impair liver function, thus impeding recovery from injury (Saville, 1975).

Much less is known about other drugs. While both licit and illicit mind enhancing drugs have been used since recorded history, in the last decades there has been growing concern about how these drugs might affect driving performance and modify injury risk. Studies of the effects of drugs on judgment and psychomotor performance have reported inconsistent results, but so far as driving-related skills are concerned, it appears that alcohol has more deleterious effects than marijuana or most therapeutic drugs. Most studies of the effects of other drugs on driving-related performance examine licit drugs (e.g. Honkanen et al., 1980; Leveille et al., 1994; Neutel, 1995; O'Hanlon et al., 1995; Ray et al., 1992; Skegg et al., 1979). While such studies show impairment associated with drugs, there is no strong evidence that their use results in elevated risks on the highway, as has been demonstrated for alcohol. Furthermore, because licit drugs are usually taken to counter other conditions, there remains a question of whether the specific individuals using the drugs would perform better in the absence of the drug or if the drugs improve their performance beyond what it would be without the treatment.

Terhune and Fell (1981) studied injured drivers presenting for treatment at a hospital in New York

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[1]Presented at the 39th Annual Meeting of Association for the Advancement of Automotive Medicine, Chicago, IL, U.S.A., 15–18 October 1995.

in 1979 and 1980. Almost half of all eligible drivers participated and were tested for alcohol and several other drugs, including tetrahydrocannabinol (THC) and cocaine. They found alcohol in slightly over one-fourth of the patients (25.3%), with THC the next most frequent drug (9.5%). Tranquilizers were the next most frequently detected drug, found in 7.5% of the patients. Cocaine was present in 2% of the drivers tested. When crash characteristics were considered, it was alcohol that was associated with crash culpability.

Recent reports have indicated that the use of illicit drugs is alarmingly high in patients admitted to major trauma centers. The samples studied vary from one report to another, with some studies including all types of trauma (Soderstrom et al., 1988; Lindenbaum et al., 1989; Rivara et al., 1989; Brookoff et al., 1993), and others focusing on motor vehicle crash victims (Stoduto et al., 1991; Kirby et al., 1992). Another study (Sloan et al., 1989) is not clear on the range of trauma, but it appears that much of it was intentional. Those studies including all types of trauma report illicit drugs present in 35–75% of the samples studied, while those based on motor vehicle crash victims report ca 40% testing positive for drugs other than alcohol. The Stoduto study included some licit drugs in their figures as well.

A more recent study by Soderstrom et al. (1993) reported alcohol and other drug use among automobile and motorcycle drivers brought to a major trauma center. Compared to an earlier study, they found a dramatic decrease in the incidence of marijuana among automobile drivers (2.7% vs 31.8% in the earlier study), but no significant decrease in marijuana use among the motorcycle drivers (32% vs 38.6% in the earlier study).

Several studies have examined the presence of drugs in fatally injured drivers. A study by Williams et al. (1985) examined fatally injured young male drivers in California and found that 81% tested positive for one or more drugs. However, because alcohol was included, and because many drivers had more than one drug, it was not clear what proportion of the drivers tested positive for illicit drugs.

Terhune et al. (1992) investigated the presence of alcohol and 43 other drugs in fatally injured drivers from seven states. All subjects were drivers of passenger cars, trucks, or motorcycles in crashes in 1990 or 1991 and died within 4 hours of the crash. Almost 18% tested positive for drugs other than alcohol. Again, alcohol was the drug most frequently detected (51.5%), with cannabis the next most frequent (6.7% of the cases). Drugs without alcohol were detected in only 6.4% of the cases. Alcohol, with or without other drugs, was most frequently associated with responsibility for the crash.

Drug testing of fatally injured truck drivers [GVW (gross vehicle weight) > 10,000 lb] found that about one-third tested positive for drugs of abuse (Sweedler and Quinlan, 1989; Crouch et al., 1993).

In both the clinical studies and the studies of fatally injured drivers, marijuana was the most frequently reported drug other than alcohol. However, there are major limitations to most of these studies. First, the clinical studies are usually limited to patients admitted to major trauma centers. Because the range of injury is severely restricted, it is more difficult to detect meaningful relationships, and hence more difficult to interpret the meaning of the presence of the drugs detected. Second, some of the studies do not clarify the basis for selection for drug testing. For example, in one study, of 1741 patients treated, usable toxicology screens were obtained on 623, or only 38% of the eligible patients (Sloan et al., 1989). Screening was conducted for patients with mental status changes that included abnormalities in level of consciousness, in behavior and/or a history of loss of consciousness. It is likely that this selection procedure increased the probability of detecting drug use, and hence the findings cannot be generalized to trauma patients in general. In another study, of 1314 patients admitted for treatment, 452 or 34%, had usable urine specimens (Rivara et al., 1989). The basis for screening is not clear. The study by Brookoff et al. (1993) has similar problems, with 42% of 520 major trauma patients tested. Again, there is no explanation of how patients were selected for testing. Third, in many of the studies, drug analyses were based in part or entirely on urine samples, so that it is not known when the drug was ingested (Lindenbaum et al., 1989; Sloan et al., 1989; Rivara et al., 1989; Kirby et al., 1992; Brookoff et al., 1993). In some instances it could have been weeks prior to the injury, because cannabinoids can remain in fat tissue for several weeks in heavy users.

The studies based on fatally injured drivers involve an even more restricted range of injury and hence must be interpreted with greater caution. In at least one of these studies it is not clear what proportion of the screening was based on urine samples rather than blood samples, again raising questions of when the drugs were ingested (Crouch et al., 1993).

When the studies include both motor vehicle crash victims and other trauma victims, highest levels of drug use are reported for patients suffering from penetrating wounds and assaults, suggesting that the injury may result from activities related to the illicit status of the drug. That is, if the drug were legal and available, the behavior leading to injury may be less likely to occur. In contrast, injury resulting from a motor vehicle crash is more likely to result from drug

impairment of performance. It is this group of injury patients that this study addressed.

This study examines the crash characteristics of occupants of passenger vehicles who were evaluated in an Emergency Department (ED) for injury following a motor vehicle crash. The purpose of the study was to determine the relationships between alcohol and three illicit drugs (marijuana, cocaine and opiates) and injury, taking into account crash characteristics known to be associated with injury. This report describes the crash characteristics as a function of alcohol and the illicit drugs.

While it is recognized that alcohol is a drug, for purposes of this paper, the term drug will refer to the illicit drugs included in the study.

METHODS

Subjects were recruited from patients presenting to two EDs, one in a large University hospital certified as a Level 1 Trauma Center and the other in a large community teaching hospital affiliated with the University hospital. Data collection occurred over a 29-month period in the University hospital (April 1992–August 1994) and a 15-month period in the community hospital (April 1993–June 1994). All patients included were presenting for treatment of motor vehicle injury. Because the volume of such patients varies across time of day and day of week, project personnel were not evenly distributed across all shifts. All evening shifts (3:30 P.M.–11:30 P.M.) were covered in both hospitals during the respective data collection periods. In the University hospital a sample of other shifts was also included. Because almost all patients brought to the ED during the late night shift were admitted, initial efforts to sample these shifts were modified. For patients who were admitted on the late night shift, blood samples were drawn and analyzed for alcohol content for clinical use. Another blood sample was also drawn and stored for research analyses, in the event the patient subsequently consented to participate in the study.

Alcohol testing was conducted by whole blood analysis using gas chromatography. Drug testing was also performed on whole blood[2]. Tests were not conducted for other drugs, such as tranquilizers.

[2]Using radioimmunoassay, initial screening was performed for cocaine metabolites (benzoylecgonine), cannabinoid metabolites [THCA (11-nor-delta-9-tetrahydrocannabinol-9-carboxylic acid), 11-nor-delta-8-tetrahydrocannabinol-9-carboxylic acid] and opiates (morphine). Cutoffs, in nanograms per milliliter (ng ml^{-1}) were, respectively, 50, 10 and 50. Samples testing positive for radioimmune assay were then analyzed using gas chromatography and mass spectroscopy (GC/MS analysis) for quantitative results. The drugs/metabolites tested for were cocaine, benzoylecgonine, morphine, codeine, THC (delta-9-tetrahydrocannabinol-9-carboxylic acid) and THCA. Cutoffs were, in ng ml^{-1}, respectively: 10, 10, 20, 20, 1, 2.

Certain patients were excluded, including patients transferred from other hospitals. Waller (1995) pointed out the biases introduced when studies based on trauma center patients include patients referred from other hospitals or treatment centers. Because most of the subjects in this study were treated and released, and because all subjects were brought directly to the hospitals involved, the primary biases associated with trauma center studies were avoided. Also excluded were: patients <18 years of age; pregnant patients; patients who were institutionalized (e.g. in prison or a mental institution); patients who could not speak English well enough to sign consent or participate in the interview; and patients injured on private property and for whom no crash report was completed. Only patients coming or brought directly to the ED were included, because blood samples had to be drawn within 6 hours of injury in order to be included in the study. Also included were fatally injured victims brought directly to the University of Michigan Autopsy Service.

Project personnel were alerted by ED staff when a subject meeting the study criteria was identified. A project interviewer approached the patient and explained the study, requesting consent for participation. If the patient agreed, a consent form was read and signed, and blood was drawn. If the patient was too injured to provide consent, blood was drawn and stored, and consent was requested when the patient was sufficiently recovered. If analyses had already been conducted and the patient refused consent, the results were discarded. Request was also made for permission to contact the subject at a later date by telephone for a follow-up interview.

To address concern that subjects may underreport their alcohol use, permission was requested to conduct a corroborating interview from a family member or friend who would be familiar with the patient's alcohol use. The subject was free to refuse permission for such a corroborating interview, and if permission was refused, the subject was still retained in the study. While corroborating interviews were requested from all subjects, those actually chosen for such an interview included only the following:

(1) subjects with a positive BAC at the time of the crash;
(2) subjects with a diagnosis of alcoholism based on the DIS interview (see the following); and/or
(3) a sequential random sample of other subjects (those whose study code numbers ended in '0' or '1').

A corroborating interview was also requested from a family member of those subjects who died or who were too disabled to participate in the study. In

these cases, this interview substituted for the subject interview.

Five types of data were included in these analyses, namely:

(1) demographic information, obtained from hospital records and from the patient;
(2) injury data, compiled from ED and hospital records;
(3) alcohol and drug data, obtained from laboratory analyses of blood samples;
(4) crash data, from copies of the crash reports obtained from local enforcement agencies; and
(5) information on previous alcohol and drug abuse/dependence, obtained from the structured interview Diagnostic Interview Schedule (DIS), an alcohol and drug assessment based on DSM-III-R criteria (Robins et al., 1989), and information on alcohol consumption patterns during the last 3 months, 1 year previously, and at their lifetime highest period of alcohol use.

Demographic data

Demographic information included basic information on age, race, sex, marital status, education, number of children, occupation, family history of alcohol and/or drug abuse/dependence or mental illness. For patients who did not complete the interview, information was obtained on the first four variables.

Injury data

Injury data included detailed information on both injury and treatment. For purposes of this study, measures of injury included the investigating officer's estimate of injury, from the crash report; Maximum Abbreviated Injury Severity 85 (MAIS 85, Committee on Injury Scaling, 1985); the Injury Severity Score (ISS, Baker et al., 1974), and whether the patient was admitted to the hospital.

Alcohol and drug data

Alcohol and drug information was based on analyses of whole blood samples, drawn within 6 hours of the crash. Samples were shipped to Compuchem Laboratories, Inc. (now LABCORPS) in the Research Triangle Park, North Carolina, for analyses of alcohol concentrations, opiates, cannabis, and cocaine.

All subjects included in this report have an objective measure of BAC, based on a blood sample. Because not all of the subjects in the larger study had drug analyses as well, those with analyses of drugs were compared with those missing such analyses to determine whether and to what extent they differed. In this way we could determine whether our final sample could be considered representative of the full spectrum of motor vehicle crash victims coming to the ED.

Crash data

Crash data were compiled from hard copies of crash reports, usually obtained from local enforcement agencies within a few days of the crash event. One of the most powerful crash variables was the TAD (Traffic Accident Damage scale, National Safety Council, 1984), a measure of vehicle crush that is highly correlated with occupant injury.

Alcohol and drug history

Previous alcohol and drug use was determined from the DIS. It was usually administered to the subject at a later time. For patients with a diagnosis of alcohol abuse/dependence or a positive BAC, corroborating interviews were conducted with a significant other who was knowledgeable about the patient. In these instances, the patient identified the other person and agreed to their contact by study personnel.

Although the larger study includes the full range of motor vehicle injury victims, the analyses reported here are limited to occupants of passenger cars, station wagons, vans, and pickup trucks.

All data were coded and maintained in locked files. Consent requirements were scrupulously observed, and, in addition, the study had confidentiality protection from both the National Institute on Alcohol Abuse and Alcoholism and the State of Michigan.

RESULTS

Initial analyses compared those subjects for whom drug analyses were available with those subjects missing such analyses to determine if there were detectable biases in our drug-tested sample. The rest of the results are based on the drug-tested subjects only and are organized into three major areas, namely:

(1) the characteristics of the injured subjects;
(2) the characteristics of the crashes in which they were injured; and
(3) the severity of injury incurred as indicated by a number of variables.

Within each of these areas, the association with current evidence of alcohol and drug use was examined. Alcohol and/or drug use was based on analyses of blood samples.

Data were analyzed using linear or logistic regression, depending upon whether measures were continuous or dichotomous. Primary predictors were

presence of alcohol (Yes = 1, No = 0), presence of drugs (Yes = 1, No = 0), and their interaction (Both Present = 1, Other = 0). Effects were modeled simultaneously. Given significant regression effects, contingency tables were examined for differences between groups (No Alcohol or Drugs, Alcohol Only, Drugs Only, and Alcohol Plus Drugs). Because the large sample size allows detection of very small effects, we applied a strict significance level ($p < 0.001$) to comparisons reported in this paper. Effects with significance levels < 0.01 but > 0.001 are also reported as trends, suggestive for future research.

Comparison of drug-tested subjects with non-drug-tested subjects

There were 894 subjects for whom data were available for these analyses, including the blood sample analyses. However, not all subjects had interviews, and for some specific variables, for example, marital status, there were missing values. Complete blood analyses were not available on an additional 362 subjects, including:

(1) subjects for whom research blood samples were not drawn, either because they were admitted during a shift that was not in the study sampling frame, or because the protocol was not followed for those who were seen during sampled shifts (at times, such as during an ice storm, the number of patients presenting were too many for project personnel to cover); and

(2) subjects who refused to give a blood sample but consented to an alcohol breath test. To determine whether and to what extent these patients without drug analyses differed from those with drug analyses, comparisons were conducted on those variables available for both groups.

Subjects were compared on age, gender, race, TAD, single/multiple vehicle crash, evidence of alcohol problems from chart, and history of alcohol or drug abuse or dependence. There was a trend for proportionately more males than females to be included in the drug tested sample (Study sample — 51.7% male, Not tested sample—43.2% male, $p = 0.006$). Although it was concluded that those patients for whom drug testing was missed were probably not sufficiently different from those evaluated to introduce serious bias, some regressions were rerun with gender stratified to ensure that effects were consistent for men and women.

Subject characteristics

The rest of the analyses are based on the 894 subjects for whom drug analyses were conducted and who were occupants of the vehicle types of interest here. Subjects represented the full range of injury presenting to two major emergency departments, with 33.3% admitted to hospital and 66.7% treated and released. Motor vehicle crash victims who were transported directly to the morgue without coming to the ED are not included in these analyses. Of the 894 subjects in the study, 630 (70.5%) tested negative for both alcohol and drugs, 130 (14.5%) tested positive for alcohol only, 76 (8.5%) tested positive for drugs only, and 58 (6.5%) for both alcohol and drugs. Table 1 summarizes the most relevant variables by alcohol/drug group. Differences among groups were tested by univariate χ^2, with significant values indicated.

Positive BACs ranged from 0.01 to 0.375%, with 81% of positive subjects at 0.08% or higher. Of the 124 subjects who tested positive for drugs, 123 were positive for cannabis, 11 for cocaine, and nine for opiates (some had used more than one drug). Because the blood sample was drawn in close temporal proximity to the crash event, it may be assumed that any drugs detected had been used relatively recent to the crash.

Subject characteristics analyzed included sex, age, race, marital status, and prior alcohol and/or drug abuse or dependence.

Sex. The subjects were fairly evenly distributed by sex, with 51.7% male and 48.3% female. Females were less likely to test positive for alcohol, (10.3% vs 30.9% for males, $p < 0.001$), as well as for drugs (7% vs 22.7%, $p < 0.001$).

Age. Subjects ranged in age from 18 to 87. Younger patients were more likely to test positive for drugs ($p < 0.001$), and there was a trend for them to be more likely to test positive for alcohol ($p = 0.003$). When age was divided into those below age 40 and those age 40 and over, for both males and females, younger subjects were more likely to have a lifetime

Table 1. Subject, crash, and injury characteristics by alcohol/drug group

Variable	None	Alcohol	Drugs	Alc + drg
% of total subjects	70.5	14.5	8.5	6.5
% Female	57.8	28.9**	30.3**	12.1
% < Age 40	65.7	84.6*	94.7**	89.7*
% Married/Wid	50.2	34.9	15.1**	8.6
% LifeAlcDx	21.2	76.2**	50.0**	73.5*
% LifeDrgDx	9.0	22.0**	46.2**	54.3
% TAD ≥ 5	45.8	63.3*	53.3	73.7
% Single vehicle	19.6	63.9**	22.4	75.9
% Nighttime	19.1	61.7**	18.7	70.9
% Weekend	27.8	43.9**	26.3	50.0
% Belt use	77.8	40.8**	48.7**	36.2*
% K + A	31.0	54.3**	47.9*	50.0
% MAIS ≥ 2	28.7	43.9**	30.3	44.8
% AdmittedHsp	27.1	57.8**	25.0	57.9

*$p < 0.01$, univariate χ^2.
**$p < 0.001$, univariate χ^2.

diagnosis of alcohol abuse or dependence and have experienced at least one symptom of such abuse or dependence within the past year ($p<0.001$).

Race. Eighty-four percent of the subjects were white, 11% black and the rest distributed across Asian, American Indian, Pacific Islander and other; no significant differences were found for race in relation to presence or absence of alcohol or drugs at the time of testing. However, whites were more likely to have a lifetime history of alcohol abuse or dependence (35.5% for white vs 16.8% for nonwhite; $p<0.001$), as well as a lifetime history of drug abuse or dependence (17.2% of white vs 6.6% of nonwhite, $p=0.001$).

Marital status. Married/widowed subjects were less likely to test positive for drugs ($p<0.001$), but alcohol use was not significantly different. If there was a positive test for alcohol or drugs, it was almost always alcohol.

Alcohol and/or drug abuse. Drinking patterns were assessed, including current and lifetime drinking patterns. Evidence of symptoms of alcohol and/or drug abuse or dependence was examined both for lifetime history and for within the past year. The structured interview, based on the DSM-III-R criteria, determined whether a subject had ever had a diagnosis of alcohol and/or drug abuse or dependence. A subject could have had a 'lifetime' diagnosis, meaning that at one time in his life he met diagnostic criteria; a current diagnosis, that is, meeting criteria in the past year; or both.

Not surprisingly, those who had a history of alcohol abuse or dependence were more likely to test positive for alcohol (38.7% of those with lifetime history vs 6% of those with no history, $p<0.001$). However, those with a lifetime history of alcohol abuse/dependence were also more likely to test positive for other drugs (22.6% vs 7.5%, $p<0.001$). Nevertheless, of those who at some time in their life had met criteria for alcohol abuse or dependence, about half (49.6%) currently tested negative for both alcohol and drugs.

A lifetime history of drug abuse or dependence was associated with an increased probability of testing positive for drugs (39.1% vs 7.3%, $p<0.001$), but over two-fifths (44.6%) of those with such a diagnosis had neither alcohol nor drugs present. Interestingly, those with a lifetime history of drug abuse or dependence also had a higher probability of testing positive for alcohol (33.6% vs 13.2%, $p<0.001$).

Those with a current diagnosis of alcohol abuse or dependence (21.2% of the sample) were much more likely to test positive for alcohol (56% vs 6.1%, $p<0.001$) and for other drugs (27.3% vs 8.4%), just as those who met criteria for drug abuse or dependence (6.5%) had a higher probability of testing positive for drugs (58.7% vs 9%, $p<0.001$) and for alcohol (43.5% vs 14.5%, $p<0.001$). Nevertheless, fairly large proportions of both groups did not test positive for either alcohol or drugs (32% of those with recent alcohol abuse or dependence and 23.9% of those with evidence of recent drug abuse or dependence).

Summary of subject characteristics. Alcohol was found in 21% of the patients. Cannabis or marijuana, was found in 13.8%, cocaine in 1.2% and opiates in 1% (some patients tested positive for more than one drug and/or for both alcohol and drugs). Most patients had neither alcohol nor drugs present.

Use of both alcohol and other drugs was more characteristic of males. Married/widowed subjects were less likely to use drugs, but the presence of alcohol was not significantly different. Younger patients were more likely to test positive for both alcohol and other drugs, but race was not significantly associated with alcohol or drug use. History of alcohol or drug abuse or dependence increased the probability of positive test results, and recent history increased it even more. However, sizable proportions of those with a history of abuse or tolerance, even a recent history, tested negative for both alcohol and other drugs.

Crash characteristics. Analyses for all subjects included TAD for the vehicle in which the subject was riding, single vs multiple vehicle crash, nighttime vs daytime crash, and weekday vs weekend crash. TAD measures were analyzed categorically, using TAD<5 and TAD$\geqslant 5$, and also as a continuous variable. Based on a seven-point scale, higher TAD scores reflect greater vehicle crush, generally associated with greater occupant injury. Nighttime/daytime was defined as 6 P.M. to 5:59 A.M. vs 6 A.M. to 5:59 P.M. Weekday/weekend was defined as 6 A.M. Monday until 5:59 P.M. Friday vs 6 P.M. Friday to 5:59 A.M. Monday.

The total crash sample was almost evenly divided between those with TAD<5 and TAD$\geqslant 5$ (49.1% v 50.9%). Most of the crashes were multi-vehicle (70.1%), most occurred during the daytime (71.8%), and most occurred on weekdays (68.6%).

Based on the two categories of TAD, subjects testing positive for alcohol, with or without drugs, were more likely to be in more severe crashes (66% vs 48%, $p<0.001$). No significant differences were found for drugs. When TAD was analyzed as a continuous variable, alcohol again was highly significant ($p<0.001$), but drugs were not. Subjects who tested positive for alcohol were much more likely to be in single vehicle crashes (67.6% vs 19.9%, $p<0.001$) and crashes occurring at night (64.6% vs

19.1%, $p<0.001$). Alcohol positive subjects were also more likely to experience their crashes on weekends (45.7% vs 27.6%, $p<0.001$), but there were no such differences found for drugs.

Use of safety belts was the only crash variable examined that was associated with the use of both alcohol and drugs. Belt use was based on the crash-reported data. Of those using alcohol, with or without other drugs, 39.4% were reported as using safety belts; while for those using other drugs, with or without alcohol, 43.3% were reported as using belts; vs 77.8% of those with neither alcohol nor drugs ($p<0.001$). Only 49% of drivers testing positive for drugs but not alcohol were reported as wearing belts.

Although relatively few subjects (76) had drugs with no alcohol present, in general, the crash characteristics for these subjects were more similar to those for subjects with neither alcohol nor drugs than they were like those of alcohol positive occupants. Compared to the crashes for alcohol positive subjects, the crashes of occupants with drugs but no alcohol were more likely to fall into the less severe category (TAD<5), involve more than one vehicle, occur in the daytime, and occur on weekends.

Summary of crash characteristics. Patients who tested positive for alcohol had a higher proportion of more severe crashes, single vehicle crashes, nighttime crashes, and weekend crashes. The crashes of those patients testing positive for drugs with no alcohol present, were more like the crashes involving occupants with neither alcohol nor drugs. It was those with alcohol, with or without drugs, that had the most severe crashes, not those with drugs alone. The numbers for drugs are small, so the findings must be taken as tentative, but these data indicate that, for the drugs included in this study, drug use alone is associated with crashes that are more similar to those involving occupants with neither alcohol nor other drugs.

Injury characteristics

Injury was evaluated based on the officer's judgment of injury (the KABCO scale), whether the patient was admitted to hospital, the MAIS 85, the ISS, and, for admitted patients, the length of stay in the hospital.

KABCO. The KABCO scale is used by officers completing crash report forms in Michigan, with the scores defined as follows (Michigan Office of Highway Safety Planning, 1993):

(1) K: Fatal injury resulting from a motor vehicle traffic crash.

A: Incapacitating injury, any injury other than fatal which prevent the injured person from walking, driving, or normally continuing the activities which he or she was capable of performing prior to the motor vehicle traffic crash; severe lacerations, broken or distorted limbs, skull fracture, crushed chest, internal injuries, unconscious when taken from crash scene, unable to leave crash scene without assistance.

B: Non-incapacitating evident injury, any injury other than fatal and incapacitating which is evident at the scene of the crash. Includes lump on head, abrasion, minor lacerations.

C: Possible injury, any injury reported or claimed which is not a fatal, incapacitating, or non-incapacitating injury. Includes momentary unconsciousness, claim of injuries not evident, limping, complaint of pain, nausea, hysteria.

O: No injury, a situation in which there is no reason to believe that the person received any bodily harm from the crash. Includes confusion, excitement, anger, internal injuries unknown to the injured until later.

For purposes of analysis, two categories of injury were defined, namely, K+A and B+C+O. Overall, 37% of the study population suffered serious or fatal injury (K+A). Patients testing positive for alcohol, with or without drugs, were characterized by more severe injury (52.9% vs 31% of those with no alcohol or drugs, $p<0.001$). Patients testing positive for other drugs, with or without alcohol, tended to be more likely to suffer more severe injury (48.8%, $p<0.01$), as were patients testing positive for drugs only (48%, $p<0.01$).

Injury scores. Injury measures included Maximum Abbreviated Injury Score, based on the 1985 revision (MAIS 85, Committee on Injury Scaling, 1985), analyzed categorically (MAIS<2, MAIS$\geqslant$2) and as a continuous variable. Injury Severity Score (ISS 85) was analyzed as a continuous variable. MAIS 85 scores ranged from 0 to 6, with a mean of 1.4. About two-thirds (67.9%) had an MAIS<2. ISS scores ranged from 0 to 75, with a mean of 4.34.

Patients testing positive for alcohol had higher MAIS scores, whether MAIS was treated as a categorical or a continuous variable ($p<0.001$). ISS scores also tended to be higher for alcohol positive patients ($p<0.01$). Although both KABCO and ISS tended to be higher for patients testing positive for drugs, the lower belt use of this group may account for these differences (see the following).

Hospital admission. The majority of patients testing negative for alcohol and/or drugs were treated and released (72.9%), as were patients using drugs only (75%). However, patients with alcohol present, with or without drugs, were significantly more likely to be admitted (57.8%, $p<0.001$).

Table 2. Logistic regression model of admission probability, full model

Variable	Parameter estimate	p value[a]	Standardized estimate
Intercept	−3.48	0.0001	
TAD	+0.52	0.0001	+0.49
Belts	−1.46	0.0556	−0.35
TAD × Belt	+0.09	0.5209	+0.12
Sex	−0.30	0.1328	−0.08
Age	+0.03	0.0001	+0.23
Alc. Present	+1.17	0.0001	+0.23
Drg. Present	−0.10	0.8064	−0.02
Alc. × Drg.	+0.32	0.6126	+0.04
Alc.Dx	−0.15	0.5369	−0.04
Drg.Dx	+0.10	0.7394	+0.02

[a]t-test on independent significance of parameter estimate.

Probability of admission was further modeled with logistic regression. The effects of alcohol presence, drug presence, and a history of alcohol abuse/dependence or drug abuse/dependence were tested after accounting for other variables known to affect injury, namely, age, use of seat belts, extent of vehicle crush (TAD), and the interaction of use of seat belts with TAD. TAD and age were treated as continuous variables, while belts, sex, alcohol, drugs, lifetime history of alcohol abuse, and lifetime history of drug abuse were categorical variables. Tables 2 and 3 show the results of two logistic regression models, the initial one with all of these variables entered (Table 2), another with the set of covariates reduced to those that were independently significant in the first model (Table 3).

The first model was highly predictive of admission [model χ^2 (10 df) = 209.42, $p < 0.0001$; concordant = 81.4%; discordant = 18.4%; tied = 0.2%]. The reduced model was as predictive as when the larger number of variables was used [model χ^2 (6 df) = 241.65, $p < 0.0001$; concordant = 79.2%; discordant = 20.5%; tied = 0.2%]. The association of predicted probability of admission from the reduced model and observed admission was over 79% concordant. After accounting for TAD, sex, age, and belt use, alcohol presence significantly increased the probability of admission. Gender was also included in the model to correct for possible selection bias in drug testing. Drug presence and lifetime history of drug abuse/dependence did not have significant effects. TAD, belt use, age, and alcohol were all significant independent predictors of probability of admission. The presence of drugs had no effect after TAD, belt use, age, and alcohol were taken into account.

Table 3. Logistic regression model of admission probability, reduced model

Variable	Parameter estimate	p value[a]	Standardized estimate
Intercept	−3.92	0.0001	
TADs	+0.52	0.0001	+0.50
Belts	−0.78	0.0001	−0.20
Age	+0.02	0.0001	+0.20
Alc. Present	+1.12	0.0001	+0.25
Drg. Present	+0.13	0.6704	+0.02
Alc. × Drg.	−0.14	0.7548	−0.02

[a]t-test on independent significance of parameter estimate.

Length of Stay. For those patients admitted to hospital, Length of Stay was analyzed by alcohol/drug group. There were no significant differences found.

Summary of injury characteristics. Alcohol was most likely to be associated with more significant injury. This relationship persisted when other relevant variables were considered. However, the drugs investigated (marijuana, cocaine, and opiates) were not found to be associated with more severe crashes or greater injury.

DISCUSSION

This study differs from most previous studies in the literature in several important ways. First, it is not limited to fatally injured victims or patients admitted to major trauma centers. Rather, it includes the full spectrum of injured motor vehicle crash victims, most of whom are treated and released. This difference is critical, in that severe restriction of the range of injury examined severely restricts the opportunity to determine relationships between injury and other important factors (Waller, 1995). For example, if one were interested in the relationship between safety belt use and injury, a study based on patients admitted to major trauma centers would mean that, by definition, every belted person was sufficiently injured to require admission to hospital. The many times that the belt use had reduced or prevented injury would be lost, and the true effectiveness of belt use would not be revealed.

Second, the alcohol and drug analyses conducted in this study are based on blood samples drawn within 6 hours of the crash (the mean time between injury and blood draw was < 1 hour). While previous studies have included such alcohol tests, few have based drug analyses on blood samples. Urine screens are the most frequent basis for drug determination, but some drugs are detected in urine screens weeks after their ingestion.

Third, data on the injured patients were linked back to the crash reports to obtain data on crash characteristics, including indicators of crash severity. Several previous studies have included crash report data but primarily for descriptive purposes. This

study takes into account crash severity in some analyses. Without knowing something about the severity of the crash itself, it is not possible to arrive at conclusions about how alcohol and other drugs may affect the extent of the injury sustained from a given level of impact.

Fourth, detailed information on injuries was retrieved so that injury scores could be computed.

Fifth, interviews were conducted to obtain detailed histories of alcohol and drug use, including evidence of both lifetime and current alcohol and/or drug abuse or dependence. Most previous studies have not included such information, and no study has included it for patients representing the full range of injury and in relation to crash data.

No previous study has simultaneously met all these criteria.

Because only the evening shift was covered throughout the entire study, with sampling of the other shifts at only one of the two hospitals, the study population cannot be considered to be characteristic of all motor vehicle crash victims presenting to the participating hospitals. However, the sample is valid for determining how crash characteristics differ for alcohol- and drug-involved crash victims. It should also be noted that the catchment area for the emergency departments involved was limited to Southeast Michigan, and the relatively low use of illicit drugs found in this study may not be representative of the extent of drug use and driving elsewhere.

For this patient population, ca 70% of the patients presenting to the EDs of the participating hospitals tested negative for both alcohol and drugs. About one-fifth tested positive for alcohol and 15% tested positive for drugs, with some overlap in the alcohol and drug populations.

History of alcohol and drug abuse/dependence, whether lifetime or current, was related to current presence of alcohol and drugs. Interestingly, a history of alcohol abuse or dependence was associated with a higher probability of current drug use. Likewise, a history of drug abuse or dependence was associated with a higher probability of testing positive for alcohol. Nevertheless, almost half of those with such a history had neither alcohol nor drugs at the time of the crash. Alcohol use was also related to crash type, with higher rates of single vehicle, nighttime crashes with higher TAD scores. Variables most predictive of hospital admission were TAD, alcohol, age, and belt use.

In this study population, drugs were not a frequent occurrence, and when they were detected, it was predominantly marijuana. Crashes involving occupants testing positive for drugs but not alcohol were similar to crashes involving patients testing negative for both alcohol and drugs. They were more likely to be multivehicle, daytime crashes with lower TAD ratings. The only crash variable that was similar for both alcohol and drug patients was lower belt use.

When drugs were present in combination with alcohol, the crash and injury characteristics were very like those associated with alcohol alone. Thus it appears that it is alcohol that is the major problem in motor vehicle crashes and injury. These findings do not imply that illicit drugs do not impair performance. It is likely that, in our society, most illicit drugs are used under circumstances that do not entail driving. Unlike illicit drugs, alcohol is frequently purchased and consumed at public establishments, with driving almost essential for access. If drugs could be legally purchased in public places, their relationship to driving may be different.

Because this study sample includes the full range of injury, and because all subjects were tested for drugs and alcohol on the basis of blood samples drawn within 6 hours of the crash, the findings are relevant for the state of the subject at the time of injury. The findings confirm previous findings for alcohol, that is, that alcohol is associated with more severe crashes, more single vehicle crashes, and more crashes occurring at night and on weekends. The findings also confirm earlier findings that, taking into account other indicators of crash severity, the alcohol-involved persons experience greater injury. No such relationship was found for drugs, that is, there was no evidence that drugs increased the extent of injury experienced when other relevant variables were considered.

CONCLUSION

Based on alcohol and drug testing of the full range of patients presenting to emergency departments for treatment of motor vehicle crash injury, including patients treated and released as well as those admitted to hospital, alcohol is clearly the major drug associated with serious crashes and greater injury. With crash severity, age, and seat belt use taken into consideration, alcohol is still associated with more severe injury. However, patients testing positive for illicit drugs (marijuana, opiates, and cocaine), in the absence of alcohol, were in crashes very similar to those of patients with neither alcohol nor drugs. When other relevant variables were considered, these drugs were not associated with more severe crashes or greater injury.

These findings have implications for interventions and treatments of patients injured in motor vehicle crashes and taken to emergency departments. To the extent that the findings of this study may be

generalized to other geographical regions, screening for alcohol alone may have greater potential impact on highway safety than more extensive (and expensive) drug screening.

Acknowledgements—This study was supported in part by the National Institute on Alcohol Abuse and Alcoholism, RO1 AA09110. The authors are grateful for the support and assistance of the Michigan Office of the Secretary of State, the enforcement agencies providing crash data, the hospital staff, and the research staff who made this research possible.

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