ORIGINAL ARTICLE

Positive blood alcohol concentration and road accidents. A prospective study in an Italian emergency department

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Study objective: To examine if a positive blood alcohol concentration (BAC) at the time of crash (≥0.50 g/l), independently of any clinical evidence and laboratory results indicating acute alcohol intoxication, is associated with specific features of patients involved, specific types of injury, and characteristics of the accident.

Methods: In this prospective cohort study, the BAC was measured in adult patients who had been injured and who were admitted to an Italian emergency department within four hours after a road accident. Altogether 2354 trauma patients were included between January to December 1998 out of 2856 eligible subjects.

Results: BAC exceeded 0.50 g/l in 425 subjects (18.1%), but was in a toxic range (>1.00 g/l) in only 179 subjects (7.6%). BAC positivity was significantly more common in men, in young subjects, in subjects driving cars or trucks, and in persons involved in a crash during night time and at weekends. It was associated with higher trauma severity, but no differences were found in injury body distribution according to vehicle type. In multivariate logistic regression analysis, the risk of a positive BAC in injured patients at the time of crash was independently associated with night time (odds ratio: 3.48; 95% confidence intervals: 2.46 to 4.91), male sex (3.08 (2.36 to 4.01)), weekend nights (1.21 (1.05 to 1.41)), and age (0.92 (0.86 to 0.99) per decades).

Conclusion: In injured patients after a road accident, a BAC at the time of crash in a non-toxic range (≥0.50 g/l) is associated with specific characteristics of crash, as well as increased risk of higher trauma severity. More careful monitoring is needed in young men during weekend nights for highest risk of BAC positivity after a road accident.

The adverse effects of acute and chronic alcohol consumption on psychological functions, safety behaviour, and performance of driving subjects have long been reported.[1] Alcohol intoxication in driving subjects is likely to cause a crash[2]; subjects with a positive blood alcohol concentration (BAC) are more likely to be at fault in a collision,[3] and more likely to be fatally injured than non-drinking drivers.[4–6] A BAC of 0.50 g/l, or even lower,[7] may impair trauma severity and outcome of injured patients.[8] The association of alcohol with increased risk of injury after road accident is also documented, based on experimental, controlled, and epidemiological studies. For this reason, the European Union took action to promote road safety by combating driving while under the influence of alcohol in the programme for 1997–2001.[9] Most European countries have already reduced or are considering to reduce the legal limit for driving to 0.50 g/l.[10] The relation between alcohol and road accidents has not been systematically studied in Italy, where the legal limit is 0.80 g/l, but legislative measures are announced to reduce this value to 0.50 g/l.

The aim of this study was to determine the relation between a positive BAC (≥0.50 g/l) at time of road accidents and the main features and the type of injury of patients involved, as well as the main characteristics of the accident.

METHODS

Study population

We considered 4637 consecutive triaged patients admitted to a first level emergency department (ED) (50 000 patients per year; area: 170 000 inhabitants) from January to December 1998 after a road accident. Most were transported by a basic trauma life support staffed road ambulance; only less than 1% of severely injured patients were carried to the ED privately. Subjects who died at the crash scene were not considered. Eligibility criteria were age ≥14 years, and admission to the ED because of a road accident, within four hours from injury. Patients with complex or severe injuries, transferred to extra-area trauma centres, were also included and followed up until hospital discharge. When involved in a second crash, patients readmitted during the study period were enrolled a second time.

Thirty five subjects (0.8%), who died at the crash scene, were excluded. In addition, we excluded 1070 patients (23.1%) admitted to ED later than four hours after crash (mean (SD): 13 (7) hours) and 676 (14.6%), who were either aged less than 14 years, or because of triaging errors, voluntary discharged from ED. A total of 2856 were eligible for the study. Only 236 subjects were lost for protocol errors, whereas 266 refused BAC determination. The final alcohol testing rate was 82.4% (2354 of 2856 patients).

Records on patients comprised personal data, crash to ED admission time, and the main characteristics of the crash. Informed consent for blood alcohol determination was obtained from patients, or from an immediate relative when patients were unable to give consent to take part to the study. Subject anonymity was maintained by use of coded numbers. The protocol was carried out according to the Helsinki Declaration and approved by the local ethical committee. Adherence to protocol was regularly checked by a project coordinator,

Abbreviations: ED, emergency department; BAC, blood alcohol concentration

Table 1 Patients with positive (≥0.50 g/l) blood alcohol concentration (BAC) in relation to baseline characteristics and trauma severity

Patient characteristics	BAC positive	%	OR (95% CI)	p Value
Sex				
Male	340/1396	24.4	3.31 (2.57 to 4.26)	<0.001
Female	85/958	8.9		
Age				
14–19	53/309	17.2	0.83 (0.78 to 0.88)	<0.001
20–29	184/716	25.7		
30–39	78/413	18.9		
40–49	42/262	16.0		
50–59	24/192	12.5		
≥60	44/462	9.5		
New injury severity score				
1–3	197/1372	14.4	1.30 (1.19 to 1.43)	<0.001
4–8	107/493	21.7		
9–15	70/309	22.7		
16–24	31/115	27.0		
25–75	20/65	30.8		

OR indicates odds ratio and 95% CI confidence intervals.

meeting with the medical staff every week to ensure the completeness of information.

Records on crash

Patients were divided in pedestrians, bicyclists, motorcyclists, driver or passenger in a car or a truck. For each subject and for each accident, thorough information was recorded on day of the week (workdays—from Monday, 0800 to Friday, 2000—compared with weekends), daytime (day—from 0800 to 2000—compared with night), in rural compared with urban areas, in straight or bend roads, or at intersections. Other characteristics of accident were also considered (vehicle went off road, head on collision, collision or non-collision with other motor vehicles, single or multiple patients involved), as were external conditions (slippery or wet road). To better define the kinetic force acting on the human body, on the basis of vehicle deformation (only for car crashes), a crash index was considered as: grade I (side swiped), grade II (coachwork dent), grade III (occupant compartment involved), grade IV (patient trapped inside). Finally, the presence of restraint systems (seat belt, airbag, helmet) was recorded. The presence of the sole airbag was not considered an adequate protective system. Data were obtained by patients themselves, Emergency System Transportation logs, and police reports. Most of data regarding crash type were significantly different in relation to vehicle type and subjects involved (for example, pedestrians and cyclists). For this reason they were not entered into logistic analysis, and their relation to BAC positivity was only assessed in subgroup analysis.

BAC

Blood for alcohol determination was anonymously drawn from either the Emergency Medical System personnel at the crash scene, before any liquid infusion was given, or at the time of admission in ED. BAC was measured by ALC, Dade Bering Inc, Newark, USA. The method has a lower detection limit of 0.10 g/l and a coefficient of variation of 0.5% (intra-assay) and 1.9% (interassay) at lower concentration (range 0.44–0.48 g/l) and 0.6% and 5.2%, respectively at higher concentration (range 1.23–1.51 g/l). The theoretical BAC at the time of crash was calculated by reverse extrapolation: the mean rate of ethanol elimination was multiplied by the estimated elapsed crash to admission time interval and added to the BAC measured. We considered a correction factor of 0.20 g/l for every hour between crash and time of blood sampling.[11] All analyses were carried our dividing patients according to a BAC ≥0.50 g/l.

Diagnostic evaluation

Injuries were coded by trained medical personnel according to the Abbreviated Injury Scale (AIS) for any body region (head-neck, face, chest, abdomen, extremities, external).[12] The New Injury Severity Score (NISS) was calculated as the score derived from the three most severe injuries regardless of body region.[12] For statistical analysis, the NISS was classified into five severity categories according to the score (1 to 3, 4 to 8, 9 to 15, 16 to 24, and 25 to 75).[13] The first category comprised minimal injuries, excluding a priori any lesion classified as AIS ≥2. A NISS ≥16 identified only patients with multiple injuries (polytrauma). Injury assessment on hospitalised patients was obtained from the final diagnoses coded in the medical records using the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM). For patients dying in ED, the NISS was calculated from necropsy reports.

Data analysis

Mean values, standard deviations (SD), and frequencies were used to describe data distribution. Alcohol positivity was analysed by means of univariate and multivariate forward stepwise logistic regression: the odds ratio (OR) and 95% confidence intervals (95% CI) were also calculated. A one way analysis of variance was applied to the continuous variables. Statistical analyses were performed running the SPSS/PC+ statistical package on a personal computer.[14] A two tailed p value less than 0.05 was considered for statistical significance.

RESULTS

Study population

In the final cohort of 2354 adult trauma patients, 425 patients (18.1%) had a positive BAC at the time of the crash (mean (SD): 0.89 (0.71.9) g/l), but only 179 (7.6%) had toxic concentrations exceeding 1.0 g/l. Patients with positive BAC were more frequently men (table 1). The prevalence of a positive BAC increased from 17.2% in patients aged 14–19 years to a maximum of 25.7% in patients aged 20–29 years, then declined progressively ($p<0.001$) along decades of age to 9.5% in patients over 60 years (table 1).

Most patients had low severity injuries, the category of NISS from 1 to 3 accounting for 1372 subjects—that is, over 50% of total population. Polytrauma patients (NISS ≥16) were only 180 (7.6%), but 52 of these (28.9%) belonged to the BAC positive group. Indeed, BAC positive patients increased progressively ($p<0.001$) along the classes of NISS, from 14.4% in patients with a NISS ≤3 to a maximum of 30.8% in patients with NISS from 25 to 75 (table 1). Approximately two thirds of

Table 2 Patients with positive (≥050 g/l) blood alcohol concentration (BAC) in relation to vehicle type and time of accident

	Number of cases	% of total	BAC positive (%)	OR (95% CI)	p Value
Role					
Pedestrian	100	4.2	12 (12.0)	0.62 (0.36 to 1.06)	0.083
Bicyclist	351	14.9	34 (9.7)	0.49 (0.34 to 0.70)	<0.001
Motorcyclist	588	25.0	106 (18.0)	1.00 (0.75 to 1.32)	1.000
Car	1245	52.9	253 (20.3)	1.16 (0.90 to 1.49)	0.244
Truck	43	1.8	14 (32.6)	2.20 (1.25 to 3.87)	0.007
Other	27	1.1	6 (22.2)	1.30 (0.60 to 2.82)	0.507
Total	2354	100	425 (18.1)		
Day/night					
0800–2000	1665	70.7	166 (10.0)		
2000–0800	689	29.3	259 (37.6)	5.44 (4.35 to 6.79)	<0.001
Weekday					
Working	1576	66.9	233 (14.8)		
Weekend	778	33.1	192 (24.7)	1.89 (1.52 to 2.34)	<0.001

patients had lesions either in the head and neck area, or in the extremities or pelvic girdle, without significant differences in relation to BAC positivity. External lesions were also present in the large majority of patients, being significantly more common in BAC positive patients (74.8% *v* 63.0%; OR, 1.74 (95%CI 1.37 to 2.21; p<0.001). Other body areas were less frequently involved; lesions of chest and abdomen/pelvis were equally distributed in relation to BAC positivity, whereas lesions in the face area were significantly more common in BAC positive patients (7.8% *v* 4.6%; OR, 1.74; 95%CI 1.15 to 2.63; p=0.009).

At univariate analysis, no differences were found in injury body distribution according to vehicle type (not reported in detail).

Crash characteristics

The prevalence of positive BAC patients was significantly lower in bicyclists (9.7% of cases), whereas it was significantly higher only in truck occupants (table 2). The crash to sampling time interval was 65 (48) minutes, median 50 minutes (interquartile range: 32 to 79 minutes), without significant differences in relation to BAC positivity (p=0.318).

The percentage of BAC positivity increased significantly in patients involved in a crash during night time, from 2000 to 0800, and during weekends, from Friday evening (2000) to Monday morning (0800) (table 2).

Pedestrians involved in crash were generally older (mean age, 57 (23) years; p<0.001), 57.0% of them being older than 60, were usually struck by motor vehicles (89.0% of cases); similarly, bicyclists were older (53 (21) years; p<0.001), were mainly involved in an accident in urban areas (82.6%) and after collision with other motor vehicles (62.4%). In particular, only 7 of 351 patients (2.0% of cases) wore helmets. No significant relation between alcohol positivity and crash characteristics were observed.

Motorcycle riders were younger (31 (16) years; p<0.001). In relation to BAC positivity, the accident occurred more frequently at a bend in the road (33.3% *v* 14.5%; OR, 2.96; 95%CI 1.85 to 4.73; p<0.001), as a result of motorcycle run off the road (37.4% *v* 14.1%; OR, 3.63; 95%CI 2.25 to 5.87; p<0.001) and without collision with other motor vehicles (27.6% *v* 11.5%; OR, 2.95; 95%CI 1.91 to 4.55; p<0.001). Recent alcohol intake was not significantly associated with lack of helmet use (14.6% *v* 20.5%; p=0.068).

In car crashes (mean age 37.3 (16.7); p<0.001), BAC positivity was not significantly associated to driving (69.0% of cases), but was more frequently related to single patient involved, in comparison to multiple, (37.4% *v* 17.4%; OR, 2.83; 95%CI 2.02 to 3.98; p<0.001). In drinking patients crashes more commonly occurred in rural areas (27.4% *v* 12.7%; OR, 2.61; 95%CI 1.94 to 3.51; p<0.001), at a bend in the road (44.6% *v* 14.5%; OR, 4.77; 95%CI 3.50 to 6.49; p<0.001), when vehicle went off the road (39.8% *v* 13.0%; OR, 4.42; 95%CI 3.30 to 5.91; p<0.001), or head on collision (30.4% *v* 11.5%; OR, 3.35; 95%CI 2.49 to 4.51; p<0.001), with a crash index >2 (36.0% *v* 16.2%; OR, 2.92; 95%CI 2.15 to 3.96; p<0.001). Subjects with positive BAC in car accidents less frequently used safety belts (12.8% *v* 27.1%; OR, 0.40; 95%CI 0.29 to 0.53; p<0.001), and less commonly crashed into another motor vehicle (40.8% *v* 12.9%; OR, 4.64; 95%CI 3.47 to 6.22; p<0.001).

Table 3 Multivariate logistic regression analysis. Risk of BAC positivity in subjects involved in a crash, in relation to human variables, crash time, and vehicle type

	Odds ratio*	95% confidence intervals	p Value
All cases			
Night time	3.48	2.46 to 4.91	<0.001
Male gender	3.08	2.36 to 4.01	<0.001
Weekend night	1.21	1.05 to 1.41	0.009
Age	0.92	0.86 to 0.99	0.034
Men			
Night time	3.41	2.31 to 5.04	<0.001
Weekend night	3.08	1.08 to 1.51	0.004
Women			
Night time	4.45	2.78 to 7.14	<0.001
Age	0.80	0.68 to 0.95	0.008

*Odds ratio was calculated considering night time, sex, and weekend night by dichotomous variables, age by decades.

Multivariate analysis

Multivariate stepwise logistic regression analysis included in sequence night time, male sex, weekend nights, and age as independent risk factors for increased risk of BAC positivity at the time of the crash, whereas weekend and vehicle type had no significant effects. Night time was the leading risk factor in both men and women, whereas other risk factors were weekend night for men and younger age for women (table 3).

DISCUSSION

This study provides evidence that in patients injured after a road accident the presence of male sex, younger age, night time, and weekend nights are main factors associated to the increased risk of theoretical BAC ⩾0.50 g/l at the time of the crash, independently of vehicle type and injury characteristic.

Large clinical studies have been carried out to evaluate the effects of alcohol intoxication on trauma severity and outcome of patients after road accident, with conflicting results.[8] Data from EDs and police departments suggest that alcohol is significantly associated with more severe injury or fatality, largely because of the frequent association of alcohol drinking with other host related risk factors, such as speeding and misuse of restraint systems.[8] BAC positive subjects have been shown to have difficulties in keeping their motorcycle under control, because of the effects of alcohol on motor skills and reaction times.[15] We found no association between BAC positivity and driving role, but the dynamics of the crash were none the less associated with loss of control of the vehicle (bend in road, vehicle went off road). This conclusion is also supported by the finding that the type of crash more frequently involved a single vehicle without collision with other motor vehicles.

Alcohol related relative risk of fatal driver injuries has been shown to correlate with driver age and sex.[16] In our study only human factors, crash time, and vehicle type have been considered as independent variables for risk of BAC positivity, as most data regarding type of crash and patients involved are difficult to classify. On this concern, we might speculate that the relation between BAC positivity and injured patients after a road accident be primary dependent on these variables.

Most clinical studies on the association of alcohol with road trauma are flawed by methodological issues. Crash characteristics are largely different in relation to the vehicle and patients involved (bicycle, motorcycle, car), or according to the source of (patients themselves, police reports, emergency system personnel).[17] When examining the crash scene, information, such as crash dynamics, angle of impact and actual speed are difficult to obtain. To reduce these biases to a minimum, the number of subjects excluded by the analysis must also be kept to a minimum, and this was successfully achieved in the present series, where only 8.3% of eligible patients were not considered (236 of 2856).

Several previous studies were hospital based or trauma centre based, including patients in very severe conditions. This policy increases the case fatality rate, but may conceal the importance of alcohol. At our institution, a community ED, minor trauma patients are also admitted; this allowed us to recruit a large population, but the number of events in terms of mortality or polytrauma patients was less than 10% of cases. We did not separate patients admitted to our ED from those more severe patients subsequently transported to level II trauma centres (approximately 2% of total cases), whose mortality rates were higher. In addition, the 35 patients who died at the crash scene (a number larger than the number of events) had to be excluded. Patients dying at the crash scene are more likely to be alcohol intoxicated,[4] a finding that fits well with the increasing prevalence of BAC positive patients with the increasing NISS, shown in the present series.

It is well known that alcohol related changes in reaction times and loss of control of the vehicle may also occur at alcohol concentrations as low as 0.50 g/l. A few patients were sampled for alcohol measurement at the crash scene, other had blood taken in the ED. The measured BAC in patients at ED admission was used to calculate the theoretical BAC at time of crash by reverse extrapolation, considering a mean rate of ethanol elimination of 0.20 g/l per hour.[11] In our series, the theoretical cut off at crash scene, mean 1.15 (0.68) g/l, corresponded to a measured concentration between 0.10 and 0.50 g/l in 178 of 425 (41.9%) patients, a BAC under the legal limits of most European countries. It was suggested that the detrimental effect of alcohol is concentration dependent, and might continue until BAC is reduced to zero.[8] In our experience, a sensitivity analysis performed using a theoretical cut off level of 1.00 g/l—that is, in the toxic range—did not change the results.

We scored trauma severity in our patients by means of the NISS, derived from the three most severe injuries regardless of body region. Its use underlies the assumption that two patients who have the same score have sustained injures of similar severity and are expected to have similar outcomes. NISS was developed from the original Injury Severity Score (ISS), generally considered the gold standard in the assessment of injury severity. Several authors have emphasised the weakness of ISS for clinical purpose.[18] In particular, ISS ignores all but the more severe injury for any body region, failing to consider additional life threatening injuries in critical body areas, in favour of less severe ones in other regions. In the present series, the use of ISS in the statistical analysis did not change the results, but the range of value was larger using the NISS, confirming a more accurate assessment of risk.[19]

It was also suggested that alcohol might influence the specific type of injury.[8] Previous studies revealed that alcohol changes injury pattern, resulting in more severe injuries from motor vehicle crashes. In our setting logistic regression failed to find out an independent effect of BAC positivity on injury type, the main factor being trauma severity. However, it is uncertain whether a dose-response effect of alcohol on injuries exists and whether a threshold level is needed to cause deleterious effects.

Interestingly, BAC positive patients were also less likely to use restraint systems (safety belts, helmets), which are definitely useful in trauma prevention.[20 21] Whether this is the result of alcohol derived disinhibition, or simply a behavioural pattern of subjects prone to drink alcohol, is not known. Anyway, in both cases this results in a serious risk when driving.

Based on our results we recommend, also in the presence of confusing, sometimes conflicting legislation in Italy, a firm intervention to prevent alcohol impaired driving. A stricter adherence of individual member states to European programmes promoting road safety to reduce total victims of road accidents is needed. It was estimated that the number of fatalities might be reduced by 5% to 40% by stopping driving with blood alcohol levels in excess of 0.50 g/l.[22] Clinicians might counsel their patients regarding the dangers of driving a motor vehicle under the influence of alcohol or other drugs as well as for the risk of travelling in a vehicle operated by someone who is under the influence of other substances of abuse. We think that this counselling is most important for high risk patients.

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Contributors

Andrea Fabbri conceived the study, wrote the protocol, coordinated the collection of data, the interpretation of results, and wrote the paper. Giulio Marchesini, contributed to study design, interpretation

of the results, and co-wrote the paper. Antonio-Maria Morselli Labate carried out statistical analyses, and interpretation of the results. Fiorenzo Rossi, Andrea Cicognani, Massimo Dente, Tiziana Iervese took part in protocol design, study coordination, and interpretation of results. Saverio Ruggeri carried out laboratory analyses and critically reviewed the paper. Ubaldo Mengozzi contributed to interpretation and to critical revision of the paper. Alberto Vandelli contributed to study design, study coordination, interpretation of the results, and critical revision of the paper. All authors approved the final version of the paper.
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