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Research Article

ROAD TRAFFIC ACCIDENT IN IVORY COAST: DO ALCOHOL AND PSYCHOACTIVE DRUGS INFLUENCE PATTERN AND SEVERITY OF INJURIES?

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ABSTRACT

Objective: Although it is well established that alcohol increase the risk of being involved or dying in a Road Traffic Accident (RTA), whether alcohol increase the severity of injuries remains controversial. This could be attributed to differences in inclusion criteria and failure to take into account relevant confounding factors including substances use. The main purpose of our study was to assess the impact of Blood Alcohol Concentration (BAC) on the risk of being seriously injured, after controlling for casualties' characteristics, substances use and RTA circumstances. ***Method:*** 891casualties (32% female) involved in a fatal or non-fatal RTA were enrolled at hospital or Forensic Institute in Ivory Coast. Blood alcohol dosage and urine drug screening were systematically performed, and linked with medical and police data. Injuries severity was coded using the New Injury Severity Score (NISS). We used multivariate logistic regression to model the risk of serious injury in relation to BAC. ***Results:*** Our study did not demonstrate any dose-response relationship between alcohol and the severity of injuries. Findings suggest that for surviving casualties attending the emergency room following a RTA, heavy drinkers (BAC > 0.08 %) are not necessarily more severely injured (odd ratio [OR] = 0.9, $p > 0.05$) compared to moderate drinkers (BAC ≤ 0.08%, OR = 7.7, $p < 0.001$). ***Conclusion:*** Among injured casualties who are not immediately killed and are admitted to the hospital, those with moderate BAC are more at risk to suffer severe injuries. Health prevention and road safety policies should target this population.

INTRODUCTION

Mortality and morbidity due to Road Traffic Accident (RTA) are at an alarming rate in Africa. In this continent, mortality rate is the highest reaching 24.1/100,000 compared to 16/100,000 in North America and 10.3/100,000 in Europe. According to the World Health Organization, should the present trend continues, by the year 2020 mortality from RTA should be reduced by 30% in high income countries, while in low income countries it should increase by 80% (World Health Organization (W.H.O), 2013). It is also predicted that by 2020, Ministries of health in African countries will be spending 25% of their annual budgets on the treatment of physical injuries due to RTA (ISTED, 1999).

In Ivory Coast (Sub-Saharan Africa), 70% of casualties attending the emergency room in the largest teaching hospital of the capital are admitted for injuries sustained from a RTA (Konan, Assohoun, Kouassi, & Ehua, 2006).

Several studies have shown an association between the level of exposure to alcohol in road users and the severity of RTA injury or fatality (Castano, 2012; Phillips & Brewer, 2011). However, those results are balanced by studies showing no difference or even protective effect of alcohol on trauma outcomes (Plurad *et al*., 2010; Zeckey *et al*., 2011). The lack of positive association between alcohol and trauma severity could be explained by differences in outcomes definition and measurement (alcohol consumption evaluation and

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determination of injury severity) or the use of non-standardized parameters to assess injury severity. Also, studies do not usually control for the use or abuse of other psychoactive substances (defined as prescription medication or illicit substances). One episode of drug use may lead to alcohol consumption that could result in lack of coordination and a traffic-related injury (Borges *et al*., 2006).

Another explanation for the discrepancy in the literature has been attributed to selection bias resulting from triage and referral of participants in hospital-based studies (Li, Keyl, Smith, & Baker, 1997).

Finally, failure to take into account information regarding crash circumstances in hospital-based studies (Lin & Kraus, 2008) and unavailability of data on injury severity in studies based on police records (Cercarelli, Rosman, & Ryan, 1996) could have produced these inconsistent results.

In Ivory Coast alcohol consumption in the general population is a serious issue, with 25% of drinkers being *binge drinkers* (World Health Organization (W.H.O), 2013). The traffic of illicit substances and illegal selling of prescription drugs on the black market is also widespread in the country, notably for cannabis and benzodiazepines (Dano *et al*., 2013). However, there is no data examining the association between injury severity or patient's outcome after RTA and alcohol/substances consumption in all the African Sub-Saharan area.

In this study we aim to describe the pattern of RTA-related injuries and to investigate the potential association between Blood Alcohol Concentration and severity of injuries (as measured by international validated scales) in Ivory Coast, after controlling for casualties' characteristics and crash circumstances.

MATERIALS AND METHODS

Ethical issue

The study was carried out according to the Helsinki Declaration and approved by the local ethical committee namely the *Comité Consultatif National de Bioethique de Côte d'Ivoire*. Informed consent was obtained from patients or close relatives prior to taking personal data or biological samples. All nominative data were removed from the database to ensure confidentiality.

Settings and study design

A cross-sectional study was conducted in collaboration with the Emergency Department (ED) in a large teaching hospital (C.H.U. de Yopougon) and the National Institute of Forensic Medicine (IMLA) in Ivory Coast.

The ED first admits all injured patients arriving at the setting regardless of the mechanism of the injury.Then ED physicians proceed to the triage of patients to provide them with appropriate care. The admission procedure allows for data collection on all RTA casualties admitted in the ED before any triage and thus contributes to avoid selection bias resulting from triage or referral. The IMLA performs autopsies with the aim to investigate causes of death upon request of police authorities. Thus we were able to obtain information on deaths related to RTA for our study population.

Study population

From March 2012 to September 2012, consecutive RTA casualties admitted to ED (non-fatally injured) and IMLA (fatally injured) were enrolled.

Casualties were included in the study if they were 14 years and older for pedestrians, passengers, motorized two wheel and bicycle riders. The age limit was 18 years and older when casualties were motorized four-wheel drivers.

The RTA in which the casualty was involved in should have taken place on a traffic lane and have involved at least one vehicle. Non-fatally injured patients admitted to the ED more than 6 hours after the crash occurred were excluded to ensure the reliability of alcohol and substances use assessment. Fatally injured casualties were included if death has occurred on the crash scene as a result of injuries suffered in the crash, and if the delay between the crash and arrival to IMLA was less than 24 hours.

Data sources

Information was collected through questionnaires and toxicological reports.

Alcohol use

Blood samples were drawn from the cubital vein of each consenting subject shortly after admission to ED, and before any administration of medication or liquid infusion. For fatal injured victims, peripheral blood was taken preferably from a femoral vein and alternately from the heart. Alcohol use was quantified in whole blood (BAC) using gas chromatography coupled with a flame ionization detector (GC-FID) by a trained Toxicologist. A Shimadzu GC 14A was used with a 180 x 0.2 cm column packed with 100/120 mesh porapak Q. Sample was injected together with n-propanol as internal standard. The analytical procedure validation demonstrated a good linearity for calibration curve (r = 0.997), precision and accuracy were also good (RSD = 4% and 2,5%), LOD was 0.045 g/L and LOQ was 0.146 g/L.We have set a threshold at 0.02g/L to define blood alcohol positive testing based on the limit of quantification of our analytical method.

Illicit and medication drugs use

Also, urines samples were taken for multi-drugs screening by enzyme multiplied immunoassay technique (EMIT, On Sight^{TM} DOA-10 DipSan, ref. 4410-25-SU, Amgenix International, Ca, USA). The following substances were tested: amphetamines, barbiturates, benzodiazepines, cannabis, cocaine, methamphetamines, 3,4-methylenedioxy methamphetamines, methadone, opiates and tricyclic antidepressants. Medical records were examined to control for drugs administration in ED before urine sample was collected. Whenever a drug was administrated, the subject was considered to be negative for this drug.

Injury severity assessment

After a medical examination by the ED physicians or the Forensic scientist, the type, location and a full description of injury were recorded using a questionnaire.

This information was later analyzed and the severity of injuries was graded according to the *Abbreviated Injury Scale* (AIS), the *Maximum Abbreviated Injury Scale* (MAIS) and the *New Injury Severity Score* (NISS) by a Physician-Expert from the

French Institute of Sciences and Technology of Transport, Development and Networks (IFSTTAR, Lyon, France).

Injuries were categorized into nine body regions according to the AIS: Head, Face, Neck, Thorax, Abdomen, spine, upper extremities, lower extremities and External. The injury from each region of the body was rated from 0 to 6 (0 =*absence of injury*; 1 = *slight injury* [*minor*], 2 = *medium heavy injury* [*moderate*], 3 = *heavy but not life-threatening* [*serious*], 4 = *heavy and life-threatening* [*severe*], 5 = *critical with uncertain outcome* [*critical*], 6 = *deadly* [*non-survivable*].The MAIS examines and classify the most severe injury within each body region. Finally, the NISS was calculated to integrate the severity of RTA casualties sustaining multiple injuries. This score considers the three most severe injuries, regardless of body region (Brenneman, Boulanger, McLellan, & Redelmeier, 1998; Osler, Baker, & Long, 1997).

The NISS is computed as the sum of squares of the three most severe AIS (1990 revision) injuries to create an ordinal scale ranging from 1 to 75. Based on the NISS scale, injuries were categorized into "slight-medium" when NISS <9 and "serious" for NISS ≥9.

Additional data collection (potential confounders)

Emergency and IMLA data

We collected casualties' characteristics at admission in ED or IMLA, which included: sociodemographic profile, road user type, vehicle type, circumstances and time of the crash and medical/clinical outcomes.

Data from Police crash report

More detailed and additional information on the crash circumstances was retrieved from Police reports, to compensate for unreported data in ED and IMLA questionnaires.

Table 1 Characteristics and crash circumstances of injured casualties admitted to the Emergency Department and Forensic Institute following a road traffic accident (RTA)

Variables	Total casualties		BAC -		BAC +		p-value[a]
	N	%	N	%	N	%	
Age category (in year)	**891**		**550**		**120**		
< 30	388	43.5	260	47.3	46	38.3	
30-40	249	28.0	138	25.1	40	33.3	
40-50	108	12.1	62	11.3	16	13.3	0.270
> 50	69	7.7	37	6.73	9	7.5	
Unknown	77	8.6	53	9.6	9	7.5	
Gender	**891**		**550**		**120**		
Male	604	67.8	369	67.1	97	80.8	0.003**
Female	287	32.2	181	32.9	23	19.2	
Income category	**891**		**550**		**120**		
High-medium	128	14.4 50.8	74	13.4	26	21.7	
Medium-low	453	34.8	278	50.5	58	48.3	0.062
Very low & unemployed	310		198	36.0	36	30.0	
Road user type	**886**		**548**		**118**		
Driver	145	16.4 28.1	76	13.9	33	28.0	
Pedestrian	249	55.5	170	31.0	36	30.5	0.0005**
Passenger	492		302	55.1	49	41.5	
Casualty outcome	**875**		**544**		**120**		
Discharged	632	72.2	396	72.8	80	66.7	
Hospitalized	217	24.8	134	24.6	32	26.7	0.059
Deceased	26	2.9	14	2.6	8	6.7	
Psychoactive drug use	**891**		**550**		**120**		
Positive	38	4.3	23	4.2	8	6.7	
Negative	301	33.8	203	36.9	37	30.8	0.052
Not performed	552	61.9	324	58.9	75	62.5	
Road type (where RTA took place)	**889**		**549**		**119**		
Highway	399	44.9	245	44.6	50	42.0	
County/Departmental road	126	14.2	63	11.5	18	15.1	0724
Municipal road	347	39	229	41.7	48	40.3	
Unpaved road	17	1.9	12	2.2	3	2.5	
Time of crash	**859**		**531**		**116**		
Day	596	69.4	383	72.1	66	56.9	0.005**
Night	263	30.6	148	27.9	50	43.1	
06:01AM-12:00AM	294	34.2	200	37.7	18	15.5	
12:01PM-18:00PM	302	35.2	183	34.5	48	41.4	0.0002**
18:01PM-00:00PM	238	27.7	137	25.8	42	36.2	
00:01AM-06:00AM	25	2.9	11	2.1	8	6.9	
	885		**548**		**119**		
Week day	434	49	273	49.8	45	37.8	0.022**
Weekend	451	51	275	50.2	74	62.2	
Mean of transport / vehicle	**888**		**549**		**119**		
Pedestrian	245	27,6 10.8	168	30.6	35	29.4	
Two-wheel	96	61.4	51	9.3	19	16.0	0.006**
Four-wheel	545	0.23	329	59.9	64	53.8	
Other	2		1	0.2	1	0.8	

[a]p-value for the chi-square test comparing proportions in BAC- versus BAC+ subgroups
**: Statistically Significant

Table 2 Distribution and prevalence of RTA overall severity injuries in relation to the road user type and injured body regions

Body regions	Number of injuries	Pedestrians (N = 200)		Two wheels (N = 70)		Four wheels (N = 369)		
		N	%	N	%	N	%	p-value[b]
Head	140	52	26.0	17	24.3	71	19.2	0.1555
Face	143	41	20.5	17	24.3	85	23.0	0.7245
Neck	32	3	**1.5**	2	**2.9**	27	**7.3**	0.0068**
Thorax	72	13	**6.5**	4	**5.7**	55	**14.9**	0.0030**
Abdomen	10	5	2.5	0	0.0	5	1.4	-
Spine	41	11	5.5	1	1.4	29	7.9	0.1076
Upper extremities	212	68	34.0	27	38.6	117	31.7	0.5119
Lower extremities	269	104	**52.0**	36	**51.4**	129	**35.0**	0.0001**
External	38	9	4.5	4	5.7	25	6.8	0.5467

[b]p-value for Chi-square test comparing the proportions of injuries across the road user categories
**: Statistically Significant

Table 3 Univariate logistic regression analysis and injury severity risk by blood alcohol concentration and selected RTA characteristics

Studied factors	Total	Serious injury ($NISS^{9+}$)		Univariateanalysis		
	N	*N*	*%*	*crude OR*	*CI 95%*	*p-value*
Agein continue	670	53	7.91	0.98	0.95-1.01	> 0.05
Age classes in year						
<**30**(ref.)	306	30	9.80	1		
[30-40[	178	9	5.06	0.49	0.22-1.05	
[40-50[	78	4	5.13	0.49	0.17-1.45	
> 50 ans	46	4	8.70	0.87	0.29-2.61	> 0.05
Unknown	62	6	9.68	0.98	0.39-2.48	
Sex						
Male	466	43	9.23	1.97	0.97-4.00	0.06
Female(ref.)	204	10	4.90	1		
Road user type						
Driver	109	12	11.0	**2.16**	1.01-4.61	0.04
Pedestrian	206	21	10.2	**1.98**	1.04-3.78	0.03
Passenger (ref.)	351	19	5.41	1		
Income category						
High-medium(ref.)	100	4	4.0	1		
Medium-low	336	29	8.63	2.26	0.77-6.61	> 0.05
Very low & unemployed	234	20	8.55	2.24	0.74-6.73	
BAC in continue	670	53	7.91	1.25	0.94-1.66	> 0.05
BAC						
Négative(ref.)	550	38	6.91	1		
Positive	120	15	12.5	**1.92**	1.02-3.62	0.04
BAC						
Négative (ref.)	550	38	6.91	1		
[0.2 – 0.8] %	20	6	30.0	**5.77**	2.10-15.9	< 0.001
> 0.8 %	100	9	9.00	1.33	0.62-2.85	> 0.05
Psychotropes substances						
Négative(ref.)	240	11	4.58	1		
Positive	31	3	9.68	2.23	0.58-8.48	> 0.05
Missing test results	399	39	9.77	**2.25**	1.13-4.49	0.019
Time of the crash						
Day (ref.)	449	39	8.69	1		
Night	198	13	6.57	0.73	0.38-1.41	> 0.05
Week day (ref.)	318	35	11.0	1		
Weekend	349	18	5.16	**0.44**	0.24-0.79	0.006
06:01AM-12:00AM (ref.)	218	21	9.63	1		
12:01PM-18:00PM	231	18	7.79	0.79	0.41-1.53	
18:01PM-00:00PM	179	11	6.15	0.61	0.29-1.31	> 0.05
00:01AM-06:00AM	19	2	10.5	1.10	0.23-5.11	
Place of the crash						
Highway	295	26	8.81	1.74	0.88-3.42	> 0.05
County/Departmental road	81	8	9.88	2.06	0.83-5.09	> 0.05
Municipal road(ref.)	277	16	5.78	1		
Unpaved road	15	3	20.0	**4.69**	1.19-18.5	0.027
Mean of transport						
Pedestrian	203	20	9.36	**1.93**	1.02-3.66	0.042
Two wheel user	70	10	12.9	**2.95**	1.32-6.57	0.008
Four wheel user(ref.)	393	21	5.1	1		
Antagonist/Collision type						
Roadway departure	148	12	8.11	0.99	0.50-1.97	> 0.05
Fixed obstacle	68	4	5.88	0.70	0.24-2.05	
Other vehicle(s)(ref.)	443	36	8.13	1		

When a discrepancy was observed between Emergency/IMLA and Police data, the priority was given to Police data considered to be more reliable.

Statistical analysis

All statistical analyses were performed using SAS version 9.3 software.

Proportions of casualties with specific injury location were compared between negative and positive BAC using Chi-square test. We used multivariable logistic regression to model the association between alcohol consumption and injury severity, controlling for potential confounding variables. Crude and adjusted odds-ratios with 95% confidence intervals are reported.

RESULTS

Characteristics of the study sample (*Table1*)

Overall, 891 casualties met inclusion criteria and 672 (75.2%) completed a blood alcohol analysis. The population was rather young with 44% of participants being under 30 years old. More than half of injured were passengers and a majority of patients were involved in a RTA which happened on a highway (44.9%) or a municipal road (39%). There were 172 patients (18%) with a positive result for alcohol testing. Drivers, two-wheel riders, fatally injured casualties, and those involved in a night or weekend RTA were significantly more represented in the BAC+ subgroup than in the BAC- subgroup.

Patterns of injury in RTA casualties
Location of injuries

Lower extremity was the most frequent body region injured in 41% of casualties, followed by upper extremity injury in 32.9% of casualties. Face and head injuries represented respectively 23.4% and 20.5% of all injured patients.

Among pedestrians and "Two-wheel", injuries were concentrated to the lower extremities (52.0% and 51.4%) and upper extremities (34.0% and 38.6%) compared to "Four-wheel" occupants (35.0% and 31.7%). Prevalence of injuries to the thorax and neck were significantly higher in "Four-wheel" occupants (14.9% and 7.3%) compared to pedestrians (6.5% and 5.7%) and "Two-wheel" occupants (1.5% and 2.9%). Proportions of patients injured to the head and face were high, but not statistically different across the different categories of road users (Table2).

Severity of injuries

Among RTA casualties tested for alcohol, 7.9% were seriously injured with a ISS ≥ 9. The most severe injuries (MAIS6 and MAIS5) were located to the head and spine. Severe injuries to the head mainly combining skull multiple fractures along with loss of substance (craniocerebral injury) were always fatal. Severe injury to the spine included fracture of the cervical spine and paraplegia (Figure1) which resulted in paralysis or death. The most common causes of fatality in RTA casualities, were head injuries in 81.8%, followed by thorax (31.8%) and spine cord injuries (18.2%).

Pattern of injury associated with Blood Alcohol Concentration

Patients tested positive for alcohol (BAC+) were predominately injured to the face (BAC+ = 35% versus BAC- = 19.8%, $p < 0.05$). Conversely, the proportion of patients with injuries located at the lower extremity was significantly lower in BAC+ patients compared to BAC- patients (29% versus 45%). BAC- patients injured to the lower extremity were in majority "Two-wheel" riders, while the BAC+ patients injured to the face were mostly drivers.

Excluding face and lower extremities, there were no significant differences between the pattern of injury in BAC+ and BAC- patients (Figure 2).

BAC and other determinants ofinjury severity

Crude OR suggested that we should adjust for road user type, time and place of the RTA and mean of transport, since these characteristics independently increase the risk of suffering from a serious injury (Table 3).

The main objective was to evaluate the impact of BAC on the risk of serious injury.The risk of serious injury in RTA casualties by BAC (3 levels) was adjusted for age, sex, road user type, profession, psychoactive substances use, time and place of RTA, and mean of transport (Table 4).

Table 4 Final adjusted multivariable logistic regression model of the risk of injury severity in road traffic accident casualties

Studiedfactors	**Multivariateanalysis**[final]		
	adjusted OR	*IC 95%*	*p-value*
BAC			
Négative (ref.)	1		
] 0.02 – 0.08]%	**7.70**	2.48-24.2	< 0.001
> 0.08 %	0.90	0.37-2.22	> 0.05
Psychotropes substances			
Négative (ref.)	1		
Positive	1.13	0.26-4.78	> 0.05
Missing test results	**2.03**	1.01-4.36	0.04
Age classes in year			
< 30 (ref.)	1		
[30-40 [	0.51	0.23-1.16	> 0.05
[40-50 [	0.53	0.17-1.67	> 0.05
> 50 ans	0.79	0.24-2.55	> 0.05
Unknown	0.70	0.22-2.18	> 0.05
Sexe			
Male	1.56	0.72-3.39	> 0.05
Female (ref.)	1		
Time of the crash			
Week day (ref.)	1		
Weekend	**0.41**	0.22-0.76	< 0.01
Place of the crash			
Highway	**3.46**	1.53-7.83	< 0.01
County/Departmental road	**2.76**	1.05-7.25	0.03
Municipal road (ref.)	1		
Unpaved road	**5.66**	1.27-25.2	0.02
Mean of transport			
Pedestrian	**3.75**	1.70-8.50	< 0.005
Two wheel user	**4.75**	1.85-12.5	< 0.005
Four wheel user (ref.)	1		

Positive BAC below 0.08% was associated with a strong increase in the injury severity. The adjusted OR was 7.7 [2.48-24.2]. However, BAC above 0.08%was not associated with more serious injury (OR = 0.98 [0.41-2.34]).

DISCUSSION

Overall, 7.9% of casualties admitted to ED or IMLA after a RTA were severely injured (NISS ≥ 9). These findings are consistent with the observations made in a South African trauma center where the number of severely road injured patients was reported to be low (Parkinson, Kent, Aldous, Oosthuizen, & Clarke, 2013). Head injury was the main cause of mortality in our study as previously reported in many studies (Eid *et al*., 2009; Yan-Hong *et al*., 2006).

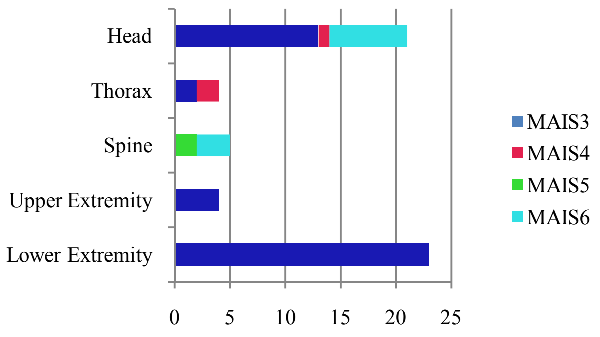

Figure1 Distribution of severe injuries (MAIS3 to MAIS6) by body regions

impact against the steering wheel, dashboard or sides of the car results in face, thorax and upper arms injuries.

Injuries profiles in our study are consistent with the mechanism described above.

The substantial difference in the frequency of thoracic trauma among “Four-wheel” occupants and the other road users may be attributed to a low use of safety belt in Ivory Coast. This is particularly true with passengers of minibuses “*Gbaka*” which are not equipped with safety devices like belt or airbags.

Our results also suggest that alcohol mayplay a role in the pattern of injuries and favour face injuries, particularly in car drivers. This is consistent with the literature that shows a well-established correlation between alcohol and cranio-facial injuries (Hyder, Wunderlich, Puvanachandra, Gururaj, & Kobusingye, 2007; Wasserberg, 2002).

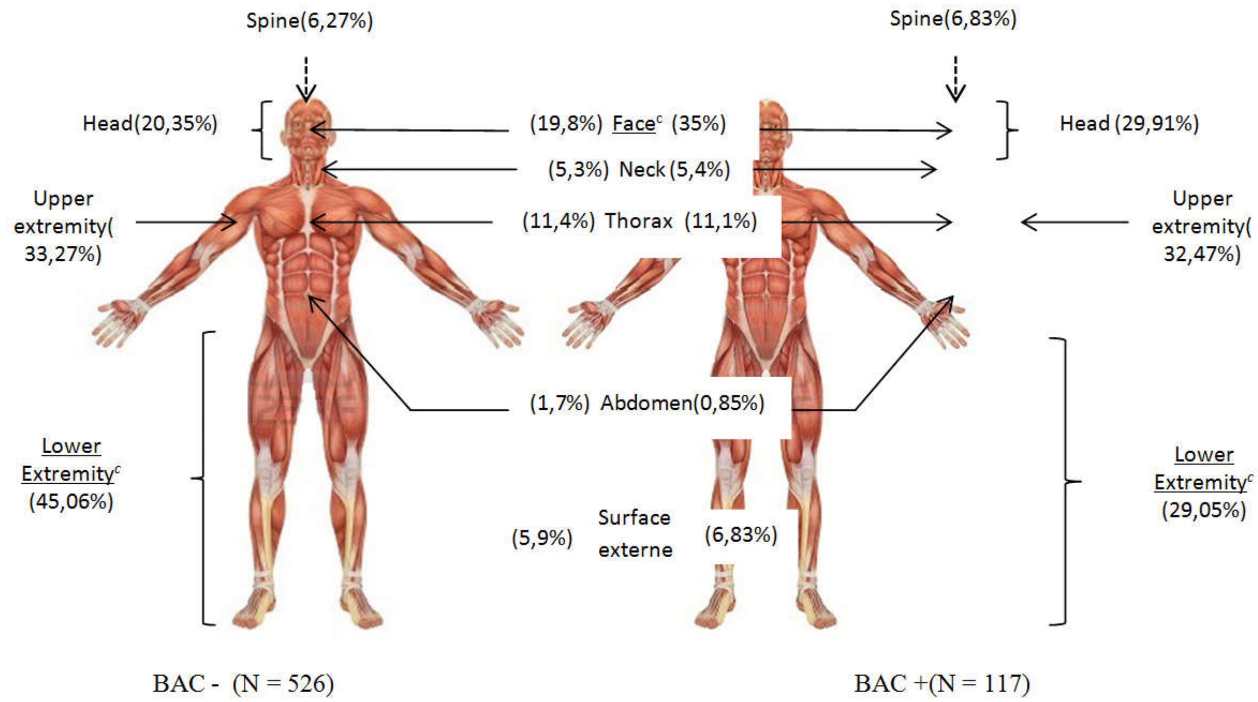

Figure 2 Breakdown of overall injuries suffered by casualties in BAC+ and BAC- subgroups

[c] *Chi square test: statistically significant difference (p-value < 0.05), comparing proportion of injuries to each body region between BAC+ (BAC > 0.02%) and BAC- (BAC < 0.02%)*

Pattern of road injuries

The pattern of injuries differed across different road users, with pedestrian and “Two-wheel” occupants most often injured to lower and upper extremities, head and face. While in “Four-wheel” occupants, thoracic and neck injuries were significantly more prevalent. These differences in injury patterns in relation to road user category could be related to the injury mechanism. During a collision against a vehicle, pedestrians classically sustain three impacts: the impact of the vehicle bumper, the impact with the bonnet and windscreen and the impact with the ground. This results into respectively: lower limb injuries, head and thorax injuries and, head and upper limb injuries (Bowley & Boffard, 2002; Parkinson *et al*., 2013). This pattern is similar in “Two-wheel” occupants.

Regarding “Four-wheel” occupants, a sudden deceleration of the vehicle results in neck injuries (whiplash effect), while

BAC and other determinants of injury severity

We found that positive BAC lower than 0.08% significantly increased the risk of sustaining a severe injury ($OR_{adjusted}$ = 7.7). Conversely, higher levels of BAC were not associated with more severe injuries.

Our findings are consistent with observations made by Friedman in a recent study including 190,612 patients admitted to a trauma center after a RTA. This study showed that the proportion of patients suffering serious injuries (ISS ≥ 16) was lower in the highest BAC group. In addition, it revealed a substantial inverse relationship between in-hospital mortality and BAC (Friedman, Sheppard, & Friedman, 2012). Similarly, Mann, in a study on 2,323 RTA casualties, has reported a trend for lower ISS score in high-alcohol group compared to lower-alcohol group. Moreover, the high-alcohol group demonstrated a lower adjusted risk of severe (ISS >15) head injury (OR

=0.65), chest (OR = 0.58) and extremity injury (OR = 0.10)(Mann, 2001).

It is now well established that alcohol increases the risk of being involved in a RTA or being responsible for a RTA. In addition, drivers under the influence of alcohol are more likely to be fatally injured than sober drivers as they tend to drive faster which results in more violent collisions. However, when we focus on RTA casualties evacuated to the hospital, conflicting results arise. This could be attributed to differences in inclusion criteria and failure to take into account relevant confounding factors such as substances use, but also to a potential selection bias. We hypothesized that this selection bias could operate in two manners:

- Hospital-based studies do not allow assessing the overall mortality as the dead at the scene of the crash are not included. In addition, as heavy drinkers are more likely to die before getting to the hospital, it is difficult to demonstrate a relationship between high BAC and the severity of injuries from hospital data;
- When involved in a RTA, survivors with a high BAC are more likely to be evacuated to the hospital because they present an altered consciousness state that could be mistaken for a severe brain injury. However, after admission to the hospital the anatomical assessment of injuries may not reveal any severe injury among these patients who are finally over represented in the high BAC subgroup.

The use of psychoactive substances showed a trend for an increasing risk of serious injury (OR = 1.14 [0.26-4.85]). Also, missing drug testing results was strongly associated with an increase in injury severity (OR = 2.25 [1.01-4.36]). Missing drug testing data was mainly due to “refusals to provide urine sample” (14.1%) or “lack of desire to urinate” (16.45%) as reported in a previous paper (Diakite *et al*, 2013). It could be hypothesized that those patients are likely to have used illicit drugs and avoid drug testing. This could then explain the association between missing drug testing and injury severity.

Strengths of our study are based on the assessment of alcohol consumption by a precise and systematic measure of BAC, which directly reflects the level of impairment in injured patients. Particularly, we measured BAC for all categories of road users including passengers and also for drivers with low BAC who are usually not tested after a negative breath analyzer test in police records based studies. Moreover, our analysis produced data that adjusted for relevant confounders including drug use and crash circumstances by linking data from hospital, toxicology lab and police records.

The greatest potential limitation in our study is related to a selection bias that could have occurred if RTA casualties with high BAC were likely to decease on the crash scene and were not sent to the Forensic Institute. The low proportion of fatally injured casualties in our study sample may be a resultof this bias. Finally, when considering results for low BAC, the occurrence of serious injury was low and the confidence interval was wide suggesting that the estimate is statistically significant but lack precision.

Further study is needed, including a larger number of fatally injured casualties, to compare intra-hospital and extra-hospital alcohol related mortality. This will allow assessing the importance of a potential selection bias and ascertaining or refuting the paradoxical protective effect of high BAC.

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Author contributions

Each author identified in the manuscript has contributed significantly to the work and agrees to the submission. Diakite, Gadegbeku, Laumon, and Malan: designed the study. Diakite: collected data and did toxicological validation and analysis. N’Diaye: did the revision of injuries and coding in NISS. Diakite and Eya-Mintsa: analyzed the data. Laumon, Gadegbeku, Malan: Critically reviewed the paper. Diakite: wrote the draft of the paper.

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