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Alcohol as a risk factor for unintentional rail injury fatalities during daylight hours

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Railway fatalities account for approximately 10% of transport fatalities in Cape Town. The objective of this study was to examine alcohol intoxication as a risk factor during daylight hours by conducting a case–control study to compare rail passenger and pedestrian fatalities (cases) with motor vehicle passenger and pedestrian fatalities (controls). Rail passenger and rail pedestrian fatalities were defined as cases with motor vehicle passenger and pedestrian fatalities as the respective controls. Data were collected from post-mortem reports at two mortuaries from 1994 to 1996. Blood alcohol concentration was the dependent variable. The independent variables were age, gender, date of death, day of week, time of injury and external cause of death. The late afternoon and early evening period from 1600 hours to 1900 hours had the highest frequency of fatalities for all case and control groups. Of the 56 predominately male (89%) railway passenger cases with an average age of 34.5 (SD 12.5) years, Friday (27%) was the most frequent day of death. Railway pedestrian cases (89% male, average age 36.8 years (SD 13.3)) were more likely to be killed on a Monday (11% of cases). Among the controls, motor vehicle passengers (63% male, average age 39.9 (SD 15.5)) were more likely to die on a Sunday (25%) and pedestrians (82% male, average age 41 (SD 14.7)) on a Saturday (21%). The study showed that alcohol consumption is an important risk factor for rail fatalities during daylight hours, with rail passenger fatalities being 4.71 (1.72–12.88) and rail pedestrian fatalities 1.62 (0.98–2.69) times more likely to be intoxicated than the respective controls. The results provide more evidence for public health campaigners to tackle endemic alcohol abuse and to develop diverse interventions that do not exclusively target motor vehicle drivers.

Keywords: Rail; Pedestrian; Passenger; Alcohol; Fatal injury

1. Introduction

In South Africa, transport-related injuries contribute substantially to the burden of disease (Bradshaw *et al.* 2003), especially among the poor and disadvantaged (Bradshaw *et al.* 1992). In the mid 1990s, transport fatalities accounted for approximately 30% of all injury fatalities in Cape Town and more than half had positive blood alcohol concentrations

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(BAC) (Lerer *et al.* 1995, Cape Town Non-natural Mortality Study Group and the Health Consulting Office 1996). Deaths on the city's railways were an important subset, accounting for between 11% and 14% of all transport fatalities and the number of deaths per commuter kilometre travelled was only marginally lower than the provincial road fatality rate (Matzopoulos and Lerer 1998). This was an untenable situation, as rail travel is regarded in industrialized countries as one of the safest means of public transport (British Medical Association 1987, Ward and Wilde 1995).

Cape Town, a large city of approximately 3 million inhabitants in South Africa's Western Cape Province, has a well-developed railway infrastructure that transported an estimated 300 000 commuters daily during the mid 1990s. A study of the local rail utility found that unlike industrialized nations, where railway injuries and fatalities are associated mainly with suicidal behaviour (Schmidtke 1994, Symonds 1994), rail disasters (Cugnoni *et al.* 1994) and collisions with motor vehicles at level crossings (Ward and Wilde 1995), the situation in Cape Town was compounded by criminality and gross risk-taking by commuters (Lerer and Matzopoulos 1995). Informal settlements next to railway lines in peri-urban areas substantially increased the number of pedestrians at risk. The study recommended that the utility of the injury surveillance system be improved and that a framework be developed for the application of public health solutions in the form of re-engineering, education and enforcement. Possible risk factors that were identified included overcrowding, criminal violence, risk-taking behaviour by commuters and the excessive use of alcohol (Lerer and Matzopoloulos 1995, 1996). Some of the suggested interventions that have been implemented include the re-engineering of commuter carriages and increasing security personnel at stations and on trains. However, the most noticeable omission from their injury prevention initiatives was a cohesive strategy to address the alcohol issue, despite the study showing that more than 40% of fatalities (including those caused by violence) had positive BAC (Lerer and Matzopoulos 1995, 1996).

Several studies have demonstrated the strong association between alcohol and rail-related injuries (South Australian Health Commission 1991, Cina *et al.* 1994, Pelletier 1997). Despite the strong association between alcohol intoxication and rail fatalities and road pedestrian fatalities, which have been shown to have higher BAC than any other transport user group (Butchart 2000, Burrows *et al.* 2002; Sukhai 2002), prevention efforts in South Africa have targeted motor vehicle drivers exclusively through media campaigns and enforcement of 'drink driving' regulations penalizing drivers with BAC greater than 0.05 g/100 ml. Eight years after the Medical Research Council's study identified alcohol as a risk factor for rail commuting fatalities, 35% of South Africa's rail fatalities tested positive for alcohol (Sukhai 2002), alcohol is still advertised at railway stations and drunken people continue to access the track and stations in the absence of effective barriers, particularly in peri-urban communities.

The purpose of this study was to determine the relationship between alcohol consumption and the risk of daytime railway injury by comparing BAC among four mutually exclusive groups of transport-related fatalities (i.e. rail passenger, rail pedestrian, motor vehicle passenger and motor vehicle pedestrian fatalities) in Cape Town over a 3-year period.

2. Methods

2.1. *Study design*

A retrospective analysis of secondary data from the two state mortuaries was conducted for the period 1 January 1994 to 31 December 1996. A case–control study design was used with two separate comparisons between unintentional railway-related and motor vehicle fatalities. The two groups of cases comprised railway pedestrian and railway passenger fatalities, while motor vehicle pedestrian and motor vehicle passenger fatalities were the respective control groups.

2.2. *Data sources*

The state mortuaries were assumed to provide full coverage of non-natural deaths in the city due to South Africa's strict medico-legal code requiring that all non-natural deaths be examined by a district surgeon, forensic pathologist or medical practitioner, under the Inquests Act of 1959 (Republic of South Africa 1959). Blood was analysed for alcohol concentration, using standard headspace gas chromatography, at the State Chemical Laboratory in Cape Town and results were attached to the post-mortem reports at the two mortuaries. Transport-related fatalities presenting to the mortuaries were divided into four mutually exclusive groups: (1) railway passengers; (2) motor vehicle passengers; (3) railway pedestrians; and (4) motor vehicle pedestrians. The ancillary post-mortem reports did not always indicate whether the rail fatality was unintentional, self-inflicted or violence-related. The incident report forms completed by railway personnel in compliance with the Machinery and Occupational Safety Act of 1983 and subsequent Occupational Health and Safety Act of 1995 were used to identify the unintentional fatalities (Republic of South Africa 1983, 1995). Railway fatalities due to violence and that were self-inflicted were excluded. It was assumed that all the motor vehicle fatalities were unintentional.

2.3. *Exclusions*

Every third motor vehicle pedestrian fatality record was reviewed, as there were considerably more of these than the other transport deaths. Death records were reviewed for 369 motor vehicle passenger, 666 (out of a possible 1999) motor vehicle pedestrian and 399 rail (passenger and pedestrian) fatalities. The rail fatalities were allocated to passenger and pedestrian groups based on information from the Metrorail incident report forms.

A total of 969 fatalities were excluded (table 1) due to the following three exclusion criteria imposed to enhance data quality and comparability: (1) fatalities due to the late effects of the injury (more than 6 hours after), as alcohol testing would not reflect the degree of intoxication at the time of injury; (2) minors younger than 18 years, as blood alcohol measurements were not routinely collected; and (3) fatalities that occurred after dark (between 1900 hours and 0600 hours). These were excluded, as the railway reports for fatalities in this time period were unreliable. Manner of death was usually recorded as unknown, and in the few cases where manner of death was specified there was too little information about the events preceding the injury to determine whether fatalities were unintentional, self-inflicted or violence-related.

The reason for the unreliable reporting, apart from poor visibility, was that railway personnel had to rely on eyewitness accounts to complete their reports. Site visits and interviews with train drivers and ticket collectors indicated that fears for personal safety increased at night-time and railway personnel were reluctant to approach bystanders. The threat of violence was confirmed by reviewing the incident report forms for fatal and non-fatal injuries, which indicated that more than 70% of violence-related incidents occurred after dark.

2.4. *Analysis*

BAC was stratified into two categories for analysis: unintoxicated ($BAC < 0.05$) and intoxicated ($BAC \geqslant 0.05$) as 0.05 g/100 ml is the legal limit for driving a motor vehicle in South Africa and denotes a moderate degree of intoxication. Odds ratios (OR) were used to approximate relative risk and a stepwise logistic regression model was fitted to each comparison group with the *p*-value for removal set at a level of 0.05. The independent variables were age, gender, day of week, time of injury and mechanism of death. The student t-test was used to compare the mean age and time of death and the chi-square test was used to compare categorical variables for the univariate analysis.

3. Results

The relative severity of railway injuries meant that fewer deaths due to late effects were excluded, and as trains were not in use between 2300 hours and 0500 hours, fewer night-time railway deaths were excluded than for the road traffic groups. BAC was available for 435 (94%) of the fatalities, including 56 (100%) of the railway passengers, 65 (75%) of the motor vehicle passengers, 181 (97%) of the railway pedestrians and 133 (99%) of the motor vehicle pedestrian fatalities. Forensic pathologists did not routinely perform BAC analysis for passengers killed in public transport collisions involving minibus (route) taxis and buses; hence, the large number of missing BAC values for motor vehicle passenger fatalities. Other missing BAC were attributable to misplaced forensic records, damage to sample bottles or the sample being too small for analysis. There was 100% recording of all socio-demographic characteristics and details of the incident.

The majority of cases selected for this study were males: 89% of the 56 railway passenger and 82% of the 181 rail pedestrian fatalities. Among the controls 63% of the 65 motor vehicle passenger and 82% of the 133 pedestrian fatalities were male. The average age of the cases was 34.5 (SD 12.5) years for passengers and 36.8 (SD 13.3) for pedestrians and among the controls it was 39.9 (SD 15.5) years and 41 (SD 14.7) years among passengers and pedestrians respectively. Friday was the most frequent day of death for railway passengers (27% of cases) and for pedestrians it was Monday (11% of cases). Among the

Table 1. Cases excluded and included in the study.

	Excluded			
	Late effects	Age	Time	Included
Railway fatalities (n = 399)	34 (9%)	25 (6%)	87 (22%)	243 (61%)
Motor vehicle passenger fatalities (n = 369)	97 (26%)	31 (8%)	154 (43%)	87 (25%)
Motor vehicle pedestrian fatalities (n = 666)	157 (24%)	103 (15%)	271 (41%)	135 (20%)
Total reviewed (n = 1434)	288 (20%)	159 (11%)	512 (36%)	465 (32%)

controls Sundays (25%) and Saturdays (21%) were the most frequent days for passenger and pedestrian fatalities respectively. The late afternoon and early evening period from 1600 hours to 1900 hours had the highest frequency of fatalities for all case and control groups.

Table 2 shows the proportion of fatalities by BAC, as well as the mean and standard deviation of the BAC for the non-zero readings. For the fatal incidents that occurred during daylight hours, more of the railway passengers (54%) were intoxicated than among the motor vehicle passenger fatalities (20%) and the same was true for the railway pedestrians (51%) and motor vehicle pedestrian fatalities (45%). However, among the fatalities that tested positive, motor vehicle pedestrian fatalities had the highest mean BAC.

Table 3 shows the univariate analysis for the association between the causes of death and each of the covariates.

3.1. *Passenger fatalities*

The OR for intoxication (BAC $\geqslant$ 0.05 g/100 ml) among rail passenger vs. motor vehicle passenger fatalities during daylight hours was 4.00 (1.79; 8.92). The final model was adjusted for age, gender, year, day and time of death and the adjusted ratio for intoxication was 4.71 (1.72; 12.88). Further analysis showed that gender modified the effect of BAC on the cause of death ($p = 0.024$), with a much larger OR of 78.25 (5.29; 999.00) for females compared to 2.00 (0.78; 5.12) for males. Although the OR was exaggerated by the small sample size for females, female rail passenger fatalities were still significantly more intoxicated than the male passengers. Table 4 shows the BAC among rail passengers by gender.

3.2. *Pedestrian fatalities*

The OR for intoxication (BAC $\geqslant$ 0.05 g/100 ml) among rail vs. motor vehicle pedestrian fatalities was 1.27 (0.81; 1.99). The final model was adjusted for age, gender, year, day and time of death and the adjusted ratio for intoxication was 1.62 (0.98; 2.69).

The adjusted OR for the model with the remaining variable (year of death) implied that during daylight hours railway pedestrian fatalities were 62% more likely to be intoxicated than motor vehicle pedestrian fatalities. The consistently positive results for both comparisons indicated that alcohol intoxication was no less of a risk factor for rail fatalities than for motor vehicle fatalities even in the pedestrian group.

3.3. *Limitations*

Similar case–control studies have either studied the relationship between alcohol and injury severity, by comparing fatal cases and non-fatal controls (Clayton *et al.* 1977), or matched by site of the injury event, and a combination of age, gender, time of day, day of week or season of year (Haddon *et al.* 1961, Irwin *et al.* 1983). The definitive case–control study for investigating the characteristics of adult pedestrians fatally injured by motor vehicles was conducted by Haddon in 1961, in which each case was matched with an individual control at the location of death. It was not possible to replicate this design, as identifying the exact site of the injury event was not possible retrospectively. Furthermore, the infrequency of incidents relative to the number of variables that would need to be matched–age, gender, socio-economic class, time of day, day of week, proximity to month-end, exact location of incident, and circumstances of injury event (e.g. as train entered station, on closing of the train doors, etc) would have been practically infeasible. Also, in a country as violent as South Africa the timing and the location of many of the incidents suggested that collecting these data would have conceivably compromised the safety of field workers. Selection bias may also have occurred, as sober individuals would have been more likely to participate in the study, and field-workers might also have avoided young males or others perceived to be potentially dangerous.

Table 2. Blood alcohol concentrations (BAC) by transport user group.

	BAC (g/100 ml)				
Fatality group	BAC = 0	BAC < 0.05	BAC $\geqslant$ 0.05	Mean	SD*
Passenger (n = 121)					
Rail (n = 56)	23 (35%)	26 (40%)	30 (54%)	0.178	0.099
Motor vehicle (n = 65)	49 (75%)	52 (80%)	13 (20%)	0.168	0.111
Pedestrian (n = 314)					
Rail (n = 181)	83 (46%)	88 (49%)	93 (52%)	0.209	0.092
Motor vehicle (n = 133)	71 (53%)	73 (55%)	60 (45%)	0.217	0.091
Total (n = 435)	226 (52%)	239 (55%)	196 (45%)	0.196	0.95

*Mean for the positive BAC group.

Table 3. Univariate analysis for passenger (n = 121) and pedestrian fatalities (n = 314).

Variable	Rail (n = 56)	Motor vehicle (n = 65)	*p*-value
Passengers			
Age (years)			
mean (SD)	34.5 (12.48)	39.9 (15.45)	0.033
Gender			
Male	89%	56%	0.001
Female	11%	44%	
Year of death			
1994	29%	29%	0.091
1995	45%	29%	
1996	27%	43%	
Day of week			
Monday	11%	20%	0.017
Tuesday	13%	10%	
Wednesday	18%	13%	
Thursday	11%	12%	
Friday	27%	8%	
Saturday	14%	15%	
Sunday	7%	23%	
Time			
mean (SD)	15h12 (4h06)	13h30 (4h00)	0.006
Pedestrians			
Age (years)			0.008
mean (SD)	36.8 (13.3)	41.0 (14.7)	
Gender			
Male	81%	71%	0.032
Female	19%	29%	
Year of death			
1994	27%	36%	0.013
1995	35%	26%	
1996	38%	38%	
Day of week			
Monday	20%	14%	0.197
Tuesday	13%	11%	
Wednesday	12%	12%	
Thursday	14%	13%	
Friday	16%	13%	
Saturday	16%	22%	
Sunday	8%	16%	
Time of death	13h54 (4h01)	14h36 (3h41)	0.112

The validity of the cause of death for the rail fatalities was largely dependent on the accuracy of railway incident reports, which were completed by railway personnel with no formal medico-legal training. Although it is possible that some railway pedestrian suicides (i.e. intentional deaths) were included among the pedestrian fatalities, it is believed that this type of misclassification was infrequent. It is expected that the inclusion of suicides would reduce the mean BAC and the proportion of cases with positive BAC and, as such, would be a non-differential misclassification. Although no significant differences were detected, approximately 50% of both groups of pedestrian fatalities were intoxicated.

The exclusion of night-time fatalities was influential, as the intoxication levels of both the road and rail fatalities would have been significantly higher had these been included. As it was not possible to determine whether the railway deaths that occurred after dark were a result of violence, pedestrian or passenger incidents, or even whether the deaths occurred anywhere near where the bodies were found, it was not possible to include them in the analysis. However, the intention of the study was to compare similar commuter populations, and rail pedestrian and passenger cases (that satisfied the exclusion criteria) were only available for daylight hours. If the rail injury reporting system had been more reliable, i.e. had more information on the details of the event been available, it would have been possible to include night-time fatalities and adjust the estimates for the time of day. Further research will be required to ascertain whether railway passenger fatalities are also significantly more likely to be intoxicated during daylight hours than motor vehicle passengers after dark or whether railway passenger fatalities after dark are more likely to be intoxicated than motor vehicle passengers after dark.

4. Discussion

The percentage of intoxicated fatalities among all the user groups in this study is alarming, with more than half of the

Table 4. Blood alcohol concentrations (BAC) among rail passengers by gender.

Gender	BAC (g/100 ml)				
	BAC = 0	BAC < 0.05	BAC ⩾ 0.05	Mean	SD*
Male (n = 91)					
Rail (n = 50)	22 (44%)	25 (50%)	25 (50%)	0.173	0.097
Motor vehicle (n = 41)	28 (68%)	30 (73%)	11 (27%)	0.188	0.110
Female (n = 30)					
Rail (n = 6)	1 (17%)	1 (17%)	5 (83%)	0.21	0.119
Motor vehicle (n = 24)	21 (88%)	22 (92%)	2 (8%)	0.08	0.07

*Mean for the positive BAC group.

railway pedestrian and passenger fatalities, as well as 45% of the motor-vehicle pedestrian and 20% of the motor-vehicle passenger fatalities, having BAC that exceeded 0.05 g/100 ml. In this study the risk of intoxication among rail pedestrians is as high as among motor vehicle pedestrian fatalities during daylight hours, and for rail passengers it is significantly higher than among motor vehicle passenger fatalities. Reducing legal blood alcohol limits is associated with a significant decline in the proportion of crashes involving fatally injured drivers (Hingson *et al.* 1996) and relates back to the Grand Rapids study, which described risk at different alcohol levels. The study showed that BAC greater than 0.04 g/100 ml is associated with increased collision rates (Borkenstein *et al.* 1964). The alcohol intoxication level of 0.05 g/100 ml used in this study is based on the current drink driving law (Republic of South Africa 1989) and highlights the important role that alcohol plays in rail fatalities at a level deemed to be significant by transport policy-makers.

However, it was in the comparison of the rail and motor vehicle passenger fatalities that the most significant differences in intoxication levels were observed. Railway passenger fatalities were 4.72 times more likely to be intoxicated than motor vehicle passenger fatalities during daylight hours, controlling for age, gender, day of week, time of injury and mechanism of death. High levels of intoxication among railway passengers have also been recognized outside South Africa, with one Australian study revealing that more rail fatalities were alcohol positive (50%) than road fatalities (41%) and that mean BAC among railway fatalities that tested positive was also considerably higher (0.26 g/100 ml compared to 0.15 g/100 ml) (South Australian Health Commission 1991). One explanation for alcohol being a risk factor for injury among railroad passengers and not among motor vehicle passengers is that rail passengers are more active and have to negotiate several potential hazards on their journey. The arrival of the train at the platform, determining whether the train is still moving before alighting and making the step from the platform to the carriage all may be compromised by the excessive intake of alcohol.

Gender and day of the week were the significant covariates and the fact that many wage earners are paid on Friday, which corresponds with the unusually high percentage of intoxicated fatalities, has obvious implications for prevention initiatives including law enforcement. It was clear that gender was also a significant effect modifier with female railway passenger fatalities being 78 times more likely to be intoxicated than female motor vehicle passenger fatalities, compared to double the likelihood among males. The increased risk for intoxicated female railway passengers could be attributable to factors that were not included in the study, such as overcrowding, which is common on certain parts of the Cape Town rail system especially at peak travelling times, and these should be investigated further. Women are more likely to be vulnerable to the pushing and shoving that takes place when commuters attempt to board trains, particularly if they are intoxicated. One intervention that should be tested is the introduction of a limited number of carriages for women only (with the remaining carriages open to both genders), which has already been introduced in Mumbai and Delhi in India.

Several international studies have shown that pedestrians killed on the road were more likely to have alcohol in their blood than controls in the general population (Irwin *et al.* 1983, Jehle and Cottington 1988, Miles-Doan 1996) and three states in Australia have introduced legislation allowing the mandatory taking of blood samples for blood alcohol analysis from injured pedestrians who present to hospitals (Holubowycz 1995). The risk factors for alcohol-impaired pedestrians in South Africa are not yet well defined (Transportation Research Board 1990, 1993), but it is believed that the problem is compounded by drinking while walking, reckless behaviour and not being visible to drivers (Directorate of Traffic Safety 1992, 1994).

Strategies to reduce alcohol-related injuries among rail pedestrians face the same challenges as for road pedestrians, unless the underlying problem, i.e. the availability of and attitude towards alcohol, is dealt with at a much broader social level. Prevention is made difficult by the high prevalence of intoxication and the acceptance of drinking as normative social behaviour in South Africa. A comparative study of adult *per capita* consumption in 31 countries placed South Africa in twenty-first position (Hurst *et al.* 1997), suggesting that alcohol consumption is lower than many other countries. However, the official figures probably underestimate the amount of sorghum beer and illicit liquor consumed and do not take into account the large percentage of problem drinkers (Parry 2004). This was borne out by recent data that show that the estimated total alcohol consumption per drinker is highest in the WHO's Africa E region (Rehm *et al.* 2003) and almost a third of confirmed drinkers in the Western Cape engaged in risky drinking (Department of Health 2001). Nevertheless, participatory research has inspired massive community action to reduce alcohol consumption in India's Maharashta State (Bang and Bang 1991), and other successful prevention programmes to reduce alcohol consumption have also been documented (Edwards *et al.* 1994, Parry and Bennetts 1998, Room *et al.* 2000).

This study has shown that during daylight hours alcohol increases the risk of unintentional injuries of rail passengers compared to motor vehicle passengers and that alcohol has similar levels of risk for pedestrians whether they are hit by a train or motor vehicle. Although differences in levels of intoxication are clear, the differential extent to which alcohol is a causal factor is not clear, as there are many social, psychological, economic and cultural factors that may also be at work. The cases examined in this study occurred at least 8 years ago during the Cape Metrorail and the Medical Research Council research collaboration. Metrorail have subsequently implemented several of the recommendations stemming from this research (Lerer and Matzopoulos 1995, 1996) and one outcome has been a drastic reduction in BAC among Cape Town rail fatalities (Lerer *et al*. 1995, Prinsloo 2005). Nevertheless, transport authorities would do well to note the impact that alcohol intoxication has on railway passengers.

Many of Cape Town's pedestrian railway deaths occur during peak periods when commuters cross railway lines at or near stations, which requires a substantial degree of coordination in the face of oncoming trains (Lerer and Matzopoulos 1996). The findings have important prevention implications for enforcement officials, who should identify and divert intoxicated commuters. They should also note that intoxicated commuters are the preferred victims of criminal violence, sometimes being thrown from moving trains (Lerer and Matzopoulos 1996, 1997) and are also more prone to falling from trains or being caught between the train and platform.

The authors hope that the results will motivate transport authorities to test interventions to curb drunkenness on the rail system, e.g. random breath testing and barring intoxicated passengers, reducing the availability of alcohol, educational campaigns and banning alcohol advertising. While it might be premature for Metrorail, in isolation, to take a stand on the issue of alcohol consumption on trains and at stations, the study provides more evidence for public health campaigners to tackle the issue of endemic alcohol abuse in South African communities. There is a need for public health and social research to understand the role of alcohol in pedestrian fatalities in South Africa and to develop effective interventions to prevent them. Prevention should focus on far-reaching health promotion and programmes that mobilize communities against alcohol abuse. At the same time, it must be recognized that rail passengers and pedestrians in South Africa are among the most vulnerable users of transport services, and measures should be put in place to relieve their stresses, as addressing alcohol abuse alone will not reduce injuries significantly unless there are accompanying interventions to change behaviour and modify the physical environment that exposes commuters to excessive risk.

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