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Alcohol-Related Mortality Risk in Natural and Non-Natural Death Cases

ABSTRACT: Determination of the associations between alcohol influence and sudden natural death represents challenges for medicolegal investigations. The aim of this study was to investigate the prevalence of alcohol influence in medicolegal autopsies. In our study of natural and non-natural deaths cases (5496 total: 4045 males, 1451 females) were examined. Blood alcohol concentrations (BACs) were detected by headspace gas chromatographic method. We investigated the alcohol-related mortality using hierarchical log-linear statistical models. Severe BACs were detected among suicidal victims in the oldest age group (>65 years) ($\ln F = 0.442$) and among the homicide victims between the age of 40–65 years ($\ln F = 0.234$). Correlations we found between manner-of-death and sex suggested that the rate of males in accidents ($\ln F = 0.140$) and the rate of females in homicides ($\ln F = 0.193$) were higher. It was concluded that the accurate statistical mortality database may provide a huge support for the determination of alcohol effects on human health and mortality.

KEYWORDS: forensic science, blood alcohol, accident, suicide, homicide, natural death, hierarchical log-linear models

Alcohol facilitates aggressive behavior, and a strong positive correlation was found between alcohol consumption and violence (1,2). Alcohol and psychostimulants have been identified as proximal risk factors of violence (1,3); however, alcoholism and alcohol abuse are known to be greatly under-diagnosed in death certificates, a fact that biases in estimates of alcohol-related mortality (4). Detection of blood alcohol concentrations (BACs) of 50 mg/100 mL and above should be classified as a contributory risk factor in most of the violent death cases (5–7). Determination of the correlations between alcohol and sudden natural death, and the postmortem evaluation of fatal alcohol intoxications represent old and new challenges for medicolegal investigations. The source of registered acute alcohol-related deaths is mainly created by the results of medicolegal autopsies (4). The national mortality database is a valuable source in monitoring characteristics regarding natural and non-natural death.

The aim of this study was to investigate the prevalence of alcohol concentrations in sudden natural and violent death cases after medicoegal autopsies, and to determine the characteristics of alcohol-related mortality using hierarchic log-linear models.

Materials and Methods

In this study, sudden natural and non-natural death cases were examined. Suicidal, accidental, and homicide cases were included in the violent manner-of-death group. We used the definition of sudden death based on the WHO definition (8): sudden death was defined as a case that happened within 24 h of the first symptoms, there was no sign of previous diseases, and there was no external cause-of-death or any sign of violent death.

We separated the cases into three groups: I: those cases where alcohol was definitely thought to be contributory, where alcohol was related to death and caused fatal alcohol intoxication; II: those cases where alcohol was thought to be contributory to the incident that caused death such as an intoxicated individual involved in a car crash; and III: those where alcohol was considered an incidental finding.

This study was based on 5496 total (4045 males and 1451 females) autopsy cases performed at Semmelweis University Department of Forensic Medicine from January 1, 1996 to December 31, 2005. During autopsies, samples were taken for histology examination, femoral blood and urine were collected, and submitted to toxicology laboratory. We included data from decedents who died at the scene. Cases were excluded when death occurred after medical treatment. Dead bodies were stored at 4°C, and autopsies were performed on the first to third days after death. Blood samples were taken from femoral veins. BACs were determined by UNICAM ProGC headspace gas-chromatograph (UNICAM Ltd, Cambridge, UK) with flame ionization detector, using a Restek BAC-2 column (Bellefonte, PA). Data were analyzed according to the manner-of-death, age, gender, and BACs.

Influence of alcohol was categorized as slight (BAC: 51–80 mg/100 mL), mild (BAC: 81–150 mg/100 mL), moderate (BAC: 151–250 mg/100 mL), severe (BAC: 251–350 mg/100 mL), and very severe (BAC: above 351 mg/100 mL) degree. Alcohol-involved deaths were defined as those with detectable BAC of more than 50 mg/100 mL. Illicit drugs were detected including amphetamine derivatives, cocaine, opiates, tetrahidrocannabinol (THC), and lysergic acid diethyl-amide (LSD).

Hierarchical Log-Linear Statistical Models

We investigated the alcohol-related mortality using log-linear models which had been formulated for the analysis of categorical data. These models are useful for uncovering the potentially complex relationships among BACs, age, gender, and manner-of-death in a multiway crosstabulation. In log-linear models, all these variables that are used for classification are independent variables, and the dependent variable is the number of death cases. Using log-linear

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models that had been formulated, the number of cases can be expressed as a function of sex, age, cause-of-death, and BACs, and the interactions between these parameters. To obtain a linear model, the natural logs of the frequencies, rather than the actual counts were used.

In general, the model for the log of the observed frequency is given by the formula

$$\ln(F_{i,j}) = \mu + \lambda_i + \lambda_j + \lambda_{i,j},$$

where F_{ij} is the observed frequency, λ_i is the effect of one chosen parameter, λ_j is the effect of the other parameters (age, sex, cause-of-death, or BAC), and λ_{ij} is the interaction effect for the *ith* and *jth* values. The *lambda* parameters and μ are estimated from the data. The estimate for μ is simply the average of the logs of the frequencies in all categories. The *lambda* parameter is just the average log of the frequencies in a particular category minus the grand mean. Negative values of ln*F* show lower values then the average, as positive ln*F* show higher values then the average. The values <−0.2 and values >0.2 represent statistically significant differences, because 95% of cases distributed between −0.2 and +0.2 values.

Results

Categories of sudden natural, accidental, suicidal, and homicidal death cases are presented in Table 1. Suicide (ICD: X60-X84) and homicide (ICD: X85-Y09) cases were registered according to the type of external damages. There were 1127 (20.5%) traffic accidents: 640 (421 male and 219 female) pedestrians (ICD: V010-V099), 55 pedal cyclists (ICD: V10-V20), 82 motorcycle riders (ICD: V20-V29), 10 occupants of three-wheeled motor vehicles (ICD: V30-V39), 191 car drivers, 82 car passengers (ICD: V40-V49), 25 occupants of pick-up trucks or vans (ICD:V50-V59), 5 occupants of heavy transport vehicles (ICD: V60-V69), 5 bus occupants (ICD: V70-V79) and 26 other land transport accidents (ICD:V80-V89).

There were 229 (4.17%) cases with fatal alcohol intoxication (group I); 327 (5.95%) cases where alcohol was thought to be contributory to the incident that caused death, such as an intoxicated individual involved in a traffic accident (group II); and in most of the 4940 cases alcohol was considered an incidental finding (group III).

Table 2 shows the ln*F* values in the BACs, age groups, and manner-of-death interaction. Severe BACs were detected among suicidal victims in the oldest age group (>65 years) and among the homicidal victims between the age of 40–65 years. Negative BAC tests were found most frequently in the youngest age group (<25 years) with natural cause-of-death. Figure 1 represents the interaction between BACs and manner-of-death in all age groups, and severe BACs were detected in suicidal cases.

Correlation between manner-of-death and sex suggests that the rate of males in accidents (ln*F* = 0.140), and the rate of females in homicides (ln*F* = 0.193) are higher than in other manner-of-death categories.

Pathomorphological changes of nonfatal diseases were detected at a higher rate among victims with negative BAC tests. Frequency of illnesses was significantly lower among cases with severe BACs. Correlation between manner-of-death and age group (Fig. 2) shows that the rate of natural diseases increased with age; the numbers of accidents and suicides are the highest in the youngest age group, and the rate of homicide victims is the highest between 25 and 40 years (ln*F* = 0.245).

Blood alcohol concentrations, sex, and manner-of-death correlation suggested that mild (ln*F* = 0.074) and severe (ln*F* = 0.126) alcohol influences had a higher importance among male accident

TABLE 1—*Distribution of natural and non-natural death cases.*

Manner-of-Death	Male (age range: 13–94 years; median: 43 years) No. (%)	Female (age range: 14–98 years; median: 46 years) No. (%)	All (age range: 13–98 years; median: 44 years) No. (%)
Accidents	1715 (42,3)	552 (38)	2267 (41,2)
Suicides	1103 (3,27)	420 (29)	1523 (7,27)
Homicides	342 (4,8)	191 (1,13)	533 (9,7)
Natural causes	885 (21,9)	288 (19,9)	1173 (21,3)
All	4045 (100)	1451 (100)	5496 (100)

TABLE 2—*The ln*F *values in the BACs, age, and manner-of-death interaction.*

BAC	Manner-of-Death	Age (years) 0–25	25–40	40–65	>65
0–0.2‰	Natural	0.277*	−0.074	−0.096	−0.107
	Accident	−0.128	−0.035	0.011	0.152
	Suicide	0.020	0.051	0.127	−0.198
	Homicide	−0.169	0.058	−0.042	0.153
0.21–0.5‰	Natural	0.211*	−0.089	0.044	−0.167
	Accident	−0.057	−0.027	−0.054	0.138
	Suicide	−0.326*	−0.004	0.229*	0.101
	Homicide	0.172	0.120	−0.220*	−0.072
0.51–2.5‰	Natural	−0.287*	0.229*	0.012	0.047
	Accident	−0.455*	−0.011	0.151	0.316*
	Suicide	0.466*	0.069	−0.190	−0.345*
	Homicide	0.276*	−0.286*	0.027	−0.018
>2.51‰	Natural	−0.200*	−0.066	0.039	0.227
	Accident	0.640*	0.074	−0.108	−0.606*
	Suicide	−0.161	−0.115	−0.166	0.442*
	Homicide	−0.277*	0.108	0.234*	−0.063

BAC, blood alcohol concentration.
*Values of ln*F* show significant differences from the average.

FIG. 1—*Results of interaction between BACs (mg/mL) and manner-of-death.*

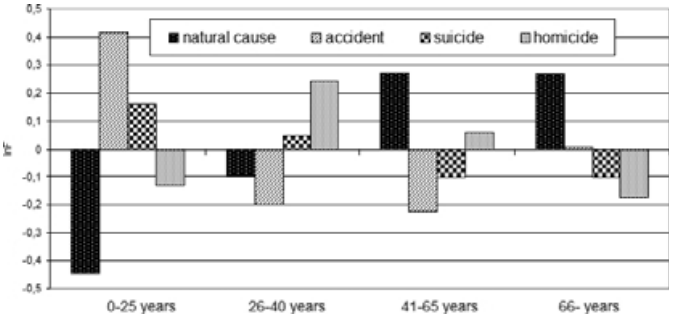

FIG. 2—*Results of interaction between age groups and manner-of-death.*

victims. Female suicide victims had more frequently higher BACs (mild BAC: $\ln F = 0.019$, severe BAC: $\ln F = 0.184$) than male suicides (mild BAC: $\ln F = -0.019$, severe BAC: $\ln F = -0.184$).

Discussion

In this study, we presented characteristics of acute alcohol influence in sudden natural and violent death cases. We confirmed study results (4,9,10) that positive blood alcohol tests can be found in a high proportion of non-natural death cases. The role of alcohol as a risk factor of accidents, suicides, homicides, and natural deaths has been frequently discussed (11–14). In our material the results of hierarchical log-linear statistical models were presented with regard to the alcohol level detected in natural and violent deaths.

Among our medicolegally investigated cases the correlation between manner-of-death and sex suggested that the rate of males in accidents, and the rate of females in homicides were higher than in other manner-of-death categories. We confirmed study results (5,6,10) stated high proportion of young victims among suicides and accidents. A study result (15) suggests that persons aged less than 30 years were more likely to have alcohol in their blood. Nordrum et al. (4) found about one-third of violent deaths among adult males are related to use of alcohol. Most of the studies presented (15–18) male dominance in violent deaths with positive blood alcohol tests. Perola et al. (19) concluded that under-diagnosis was especially prevalent in female postmortem alcohol level rates. Nordrum et al. (4) detected that coronary atherosclerosis, sudden unexpected death, and chronic alcoholism are the most frequent causes of death with BAC $\geq 0.5‰$. Shkolnikov et al. (20) estimated that medium and greater levels of alcohol intoxication occurred in a quarter of decedents recorded as dying from cardiovascular disease. Endocrine and digestive system diseases were suggested to be associated with positive BACs (21).

Traffic accidents especially have a very close correlation with BACs (14,22–24). In our material the correlation between sex, age, and manner-of-death shows that accidents occur more frequently among young males and old females. Increasing BACs among drunken drivers with chronic alcohol abuse have been reported (25). Drummer et al. (5) found that drivers killed in motor vehicle crashes and taking psychoactive drugs, particularly cannabis and strong stimulants, or two or more drugs in combination were more likely to be responsible for the crashes. THC, amphetamines, and combinations of psychoactive drugs significantly increase the risk of fatal traffic accidents (5,17).

This study confirms study results (6,10,15) that alcohol consumption is a common precursor to suicide. The proportion of positive BACs varied between 40% and 90% in reported cases (21,26). In our material more moderate and severe BACs were detected among young suicidal victims than in older age groups, and the very severe BACs were found over the age of 66 years. Most of the victims of homicide and unintentional fatal injuries had a positive BAC (27). Meta-analysis suggests (28) that aggregate percentage tested for BACs was the highest among homicide cases (88.2%).

Analysis and interpretation of BACs in autopsy specimens represent a large part of the workload at forensic medicine and toxicology laboratories. Fatal alcohol intoxication is often an open question, and it much depends on the person's age, drinking experience, and degree of tolerance development.

Limitation of This Study

We have to exclude cases with survival period and medical treatment after suffering injuries or damages. Our model includes decedents who died at the scene, and forensic autopsy was performed with postmortem BAC test. In this model chronic pathomorphological changes as fatal complication of cirrhosis hepatis were not evaluated.

Medicolegal investigation has usually been faced with problems of postmortem changes. Microorganisms (yeasts and bacteria) in putrefaction can produce alcohol in the process of fermentation, usually a mixture of ethanol and other volatile substances. When ambient temperatures are between 5°C and 20°C, postmortem alcohol production can be detected at a significant level after 48 h (29,30). In our material all the cases were autopsied in 24–72 h after death, and we stored dead bodies at +4°C. Blood ethanol level may be low in case of inadequate storage. This is usually due to contamination of the specimen by microorganisms which metabolize the ethanol to other compounds (31–34). Postmortem diffusion of ethanol across the gastric bowel wall can occur in intact and disrupted bodies (35,36).

Study results suggest (19) that estimates of prevalence of alcoholism based only on review of death certificates are to be considered with great caution. Nordrum et al. (4) suggest it is therefore relevant to question the validity of the data on alcohol-related deaths in official cause-of-death register. In our material the high BACs among suicides and homicides reflect the high level of alcohol consumption and binge drinking in Hungary (37,38). We emphasize that the high rate of detailed medicolegal autopsies of sudden death cases is essential to determine the exact cause-of-death, and to characterize the pathomorphology of a possible symptom free disease. The higher rate of autopsies provides a basis for the evaluation of toxic agent effects on natural death cases. Detection of exact cause-of-death by forensic pathologists has a prominent role in the differentiation between violence and natural death. Characterization of risk factors is important to determine preventative strategies against violent mortality. The accurate statistical mortality database may provide a huge support for the determination of alcohol effects on human health and mortality. Based on our results, we can emphasize the importance of a careful medicolegal postmortem investigation, including blood alcohol detection in every young sudden natural death and non-natural death case.

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