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The value of the post mortem analysis of carboxyhemoglobin concentration in blood – A 15-year study

Значај постморталне анализе концентрације карбоксихемоглобина у крви – петнаестогодишња студија

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The value of the post mortem analysis of carbon monoxide concentration in blood – A 15-year study

Значај постморталне анализе угљенмоноксида у крви – петнаестогодишња студија

SUMMARY

Introduction/Objective The aim of this retrospective study was to assess the carbon monoxide (CO) concentration in all autopsy cases of fire and non-fire victims – all those who have been suspected to be under influence of CO in the Belgrade area during 15-years period (1990-2005.).

Methods Correlations between concentration of HbCO, circumstances of death, vital signs, and prior health conditions, smoking and history of alcohol-abuse have been particularly analyzed in 192 autopsy cases

Results The investigation included 52 (27%) females and 140 (73%) males, average age of 50.78 years. CO poisoning has been established as a cause of death in 74 cases (38%). The manner of death in 170 cases (89%) has been an accident, in 8 (3%) suicides, in 2(1%) murders, in 11(6%) natural death, and in one case the manner of death hasn't been established. Such distribution of the manner of death differentiates this study from the others of similar type, and it's conditioned by specificity of life in this region.

Conclusion Predictors of high concentration of HbCO are: gender, cause of death, manner of death, soot aspiration, lover burn degrees. According to the results we have profiled the victim of the CO poisoning.

Keywords: carbon-monoxide; forensic medicine; epidemiology; HbCO concentration

САЖЕТАК

Увод/Циљ Циљ ретроспективне студије био је одређивање концентрације угљен-моноксида (*CO*) у свим случајевима жртава из пожара и оних који нису у вези са њим, на подручју Београда, у периоду 1990–2005, односно свих случчјева за које се сумњало да су били изложени *CO*.

Методе Посебно су анализиране у 192 случајева обдукције: корелација између концентрације карбоксихемоглобина (*HbCO*), околности умирања, виталних реакција, претходног здравственог стања, пушења и злоупотребе алкохола.

Резултати Испитивање је обухватило је 52 (27%) жена и 140 (73%) мушкараца просечне старости 50,78 година. Тровање *CO* је утврђено као узрок смрти у 74 случаја (38%). У 170 случајева (89%) радило се о задесима, у 8 (3%) о самоубиствима, у 2 (1%) о убиствима. У 11 случајева реч је било о (6%) природној смрти док у једном случају узрок смрти није установљен. Оваква расподела диференцира ову студију од сличних и условљена је специфичностима живота у региону.

Закључак Предиктори високе концентрације *HbCO:* пол, узрок смрти, начин смрти, аспирација чађи, степен изгоревања. На основу резултата, направљен је профил жртве тровања *CO*.

Кључне речи: угљен-моноксид; форензичка медицина; епидемиологија; концентрација *HbCO*

INTRODUCTION

Carbon monoxide (CO), as one of the most common toxic agents in forensic practice, is a by-product of the incomplete combustion of hydrocarbons and it originates mostly from human activity (internal combustion engines, industrial discharges, poorly functioning heating systems).

Exposure to carbon monoxide can be either intentional or accidental (industry, mines, explosions, exposure to automobile exhaust fumes or in households) [1]. Unintentional fire related deaths caused by CO poisoning are the most common, however, deaths caused by suicide or homicide are possible, but rare [2].

Carbon monoxide is impossible to detect by a person exposed to it because it is colourless, tasteless, odourless and non irritating [3]. When inhaled CO forms reversible complex with haemoglobin (Hb) known as carboxyhemoglobin (HbCO). Values of carboxyhemoglobin above 50 % saturation are usually consistent with death, values between 10 and 50 % could indicate that the individual was alive when the fire began and values below 10 % could suggest that the individual had been dead prior to the fire [4].

The aim of this retrospective study was to analyze all autopsy cases in the Belgrade area, suspected to have carbon monoxide, pointing out relations between concentration of HbCO, circumstances of death, vital signs, and prior health condition. We tried to profile the victim of CO poisoning as well as circumstances of death.

METHODS

In the Institute of forensic medicine, Belgrade University School of Medicine, retrospective analysis of 192 autopsy cases (included microscopical and toxicological findings) with suspicion on CO poisoning in the 15- years period (1990-2005.) was performed. Although CO analysis is not routine procedure during autopsy, except in arson victims, CO was analyzed when the circumstances of death, the scene investigation or the autopsy findings (the colour of the livers etc.) indicated CO poisoning. We analyzed concentration of HbCO in relation with different epidemiological parameters: sex, age, mode, manner and cause of death, circumstances of death, degree of the burns, alcochemistry, soot aspiration, smoking habits, diseases that could have influenced the sensitivity to the toxic effect of the CO. For determining the HbCO concentration in blood taken from femoral vein spectrophotometry method was used (spectrophotometer M4 QIII, Carl Zeiss). The HbCO saturation levels in our sample group were divided as follows: up to 10 % (expected in heavy smokers); from 11 to 20 % (vital sign), from 21 to 50 % (could be considered as a cause of death if combined with cardiovascular diseases), and above 50 % sufficient as a single cause of death.

Statistical analyzes were performed using SPSS software v. 18.0 (SPSS Inc., Chicago, USA). Descriptive data for all groups and variables were expressed as mean ± SD for continuous measures, or percent of a group for discrete measures. Categorical data were analyzed using the Pearson´s chi-square test. Numeric data were tested for normal distribution using the Koglomorov-Smirnov test. All numeric data in our study were not normally distributed, though the Mann-Whitney U test and Kruskal Wallis test were used. Multivariate regression analysis was performed for univariate and multivariate testing, observing the impact of HbCO concentration and risk factors on outcomes of injured. All reported p values were two-sided; differences were considered significant when p value was <0.05.

RESULTS

Acquired results are shown in table 1.

Fifty two females (27%) and 140 males (73%), aged 50,78 (1–92) years were included in the study, while males were statistically more frequent than females. There is statistically significant effect of HbCO concentration depending on the gender (Kruskal Wallis= 0.589, df=3 p>0,05). There is no statistically significant effect of HbCO concentration depending on the age (p=0,879).

In 41% of the cases concentration of HbCO was up to 10%, in 12% of cases it was 11-20%, in 21% 21-50%, and in 26% over 50%, an average of the established concentrations of HbCO in the whole sample was 28.09±2.05%.

Table 1. Parameters analyzed in relations to HbCO concentration.

Parameters		Conc. Hb CO (%)				Total
		0–10	11–20	21–50	>50	
Sex	male	64	16	28	32	140
	female	15	6	13	18	52
Age (year)	0-20	8	3	3	8	22
	21–40	20	5	11	11	47
	41–60	17	8	9	11	45
	>60	34	6	18	20	78
Atherosclerosis	yes	52	11	26	27	116
	no	27	11	15	23	76
Smoker	yes	50	15	29	29	123
	no	29	6	13	21	69
Alcohol (g%)	<0.03	66	13	29	32	140
	0.03–0.3	10	7	11	14	42
	>0.3	3	2	2	3	10
Psychiatric history	yes	5	8	0	9	22
Soot aspiration outside	yes	3	1	3	4	11
	no	9	0	0	1	10
Soot aspiration inside	yes	39	21	35	34	128
	no	28	1	4	10	43
Manner of death	natural	5	1	2	3	11
	accident	67	19	37	47	170
	suicide	3	2	2	1	8
	homicide	2	0	0	0	2
	unknown	2	0	0	0	1

CO poisoning as a cause of death by itself or in combination with chronic diseases or injuries has been established in 74 cases (38%). In 43 cases the causes of death have been burns and their complications, 50 bodies have been charred, and in 25 other, violent on non violent, causes of death have been established (brain contusion, haemorrhage, complication of mechanical trauma, electrocution, heart infarction).

When observing deaths, assumed to be related to CO poisoning, a balanced distribution regarding age can be noticed. In the group of persons up to 20 years of age was the highest percentage (36%) of HbCO concentration of over 50%, while in other groups concentration of HbCO of over 50% was established in 24% of cases, without statistically important difference.

In 76 cases (40%) there weren't atherosclerotic changes, while in 116 cases (60%) there was distinct atherosclerosis. There is no statistically important difference in HbCO concentration between smokers and non smokers. Representation of CO concentrations in groups (up to 10%, 11-20%, 21-50% and over 50%) does not show statistically significant difference between smokers and non smokers. Analysing atherosclerosis in smokers, relating to HbCO, it was found that out of 41 person with CO concentration of 21-50% 4(10%) didn't have atherosclerosis nor did they smoke (χ^2=2.65; df=3 p =0.449), 9 (22%) didn't smoke but had atherosclerosis, 10(25%) smoked but didn't have atherosclerosis, and 18 (43%) were smokers with atherosclerosis (χ^2=6.68; df=3 p=0.083 p >0.05).

Average value of blood alcohol concentration (BAC) was 0.06±0.01 g%, of which 140 cases (73%) of concentration less than 0.03 g% - 42 (22%) 0.03-0.3 g%, and 10 cases (5%) of blood alcohol higher than 0.3 g%. When cross referenced, HbCO concentrations and BAC haven't shown a statistically significant effect of degree of inebriation on exposure to CO, and therefore to HbCO, (χ^2=8.565, df=6; p=0.200 p>0.05).

In analysed sample there was total of 22 (11%) psychiatric patients, whereby in this group CO poisoning was the cause of death in 41% of the cases. The link between psychiatric condition and CO

poisoning can be seen even if we observe these parameters in summed sample where the group of psychiatric patients makes for 12% of the deaths by CO poisoning.

Relating to the scene of event, in 21 cases (11%) the body was found outdoors, and in 171 (89%) cases it was found indoors. Out of 30 victims found in cars there was only one case where HbCO concentration was over 50 %, in 17 cases (61%) HbCO of up to 10 % was established, and in remaining 36% the HbCO concentrations were between those two values. Soot aspiration was established in 139 cases (72%), while in 53 cases (28%) it hasn't been found. In every case with soot aspiration HbCO was detected.

By manner of death 170 cases (89%) were an accident, 11 (6%) were natural deaths, 8 (3%) were suicides, 2 (1%) murders, and in one case the cause and manner of death hasn't been established. Out of total sample in 92 %(176 cases) death came instantly, and in 8 cases each (4%) survival was up to 24 hours, and over 24 hours. When analysing HbCO concentration relation to the manner of death it can be noticed that the most of the CO poisonings have been established in accidental deaths.

Table 2. Relation between the degree of burns and HbCO concentration.

Burn degree	0–10%	11–20%	21-50	>50%
None	1	1	9	18
I degree	0	0	0	1
II degree	2	1	0	8
III degree	16	2	4	5
Combined II, III, IV	15	8	7	8
Total	**33**	**12**	**20**	**40**

Relations between burn degrees and HbCO concentration are shown in table 2. There is statistically significant relation between burn degrees and HbCO concentration, the lower the burn degree the higher the HbCO concentration. (χ^2=50.67; df=15; p=0.000 p<0.05).

Statistical analysis has shown that the predictors of high HbCO concentration are: gender, cause of death, manner of death, soot aspiration and burn degree.

DISCUSSION

In the Belgrade area (population of 2 mil) deaths caused by CO poisoning are the second (drug related deaths are the first) most common among intoxications [5,6]. The most common source of CO in Belgrade are home, industrial and traffic fires, as central gas heating appliances are not available. Heath and toxic fumes are the main causes of death during a fire [7]. We know that with the low levels of HbCO in victims distant from the fire rises the possibility of other toxic gases but, as this is retrospective analysis, other gases (HCN, and others causing methemoglobinemia) were not analysed during observed period [8].

Analysis of our sample in relation to gender shows that males are more represented in the total sample, but higher concentrations of HbCO are more common in females. Being that blood levels of CO are expressed relatively, with haemoglobin saturation, this can be explained with lower absolute quantity of haemoglobin in females alongside with more common anaemia, and therefore its quicker saturation rate. Unfortunately we weren't able to compare this to any examples in literature because we haven't been able to find any analysis of the type.

Our results coincide with the results of other research that no significant correlation of HbCO concentration and age had been noticed. Although there isn't any statistically significant difference, the young are more resilient to CO effects, and for death to occur higher concentrations are necessary. This can be explained with the lack of predisposed factors like anaemia, cardiovascular or lung disease.

Our study showed that analysis of the HbCO concentration was requested and done reasonably. CO poisoning was cause of death in 38% cases (HbCO over 50%, statistically highly significant), while HbCO as vital sign was found in 59% of the cases. The most important diagnostic parameter for injury vitality is simultaneous finding of elevated HbCO concentration (over 10%) and soot aspiration. There is statistically high important correlation of HbCO concentration and soot aspiration, unrelated to the scene of event (indoor/outdoor). This is logical because respiration is necessary for both, but in some cases fire is not accompanied with soot, so the positive HbCO finding is a sufficiently vital sign [5]. In our specimen all the cases with occurring soot aspiration had concentration of HbCO higher than 10%, while Bohnert (6) quotes 57% correlation. Although in 15 cases where the concentration of HbCO was over 10% soot aspiration hadn't been established. Concentration of HbCO can be elevated even without the soot aspiration, which is explained with the presence of HbCO even without the flame, also with the type of the burning material and the dynamics of fire development.

The fact that there was significant correlation between soot aspiration and high HbCO concentration (expB=11.360; p=0.08) even with the bodies found outdoors was a result of quick combustion of large quantities of accelerators spilled on the body (temperature up to 1100°C is reached within seconds). In our conditions the most common is suicidal self immolation, although concealed murder mustn't be ruled out [9, 10, 11].

It was established that in 26 cases (13%) the cause of death wasn't in any correlation with the effect of high temperature and/or CO poisoning (natural death, brain contusions, etc.), body was engulfed in flame post mortally. This confirms the validity of determining HbCO concentration in all cases where there is the effect of flame because even the negative result can contribute to solving the case.

Blood HbCO concentration was statistically high conditioned by the location where the body had been discovered (indoor/outdoor). Our analysis has shown that high concentration of HbCO is characteristic for bodies found indoors. This can be explained with that in our conditions biggest source of CO is a fire accompanied with O_2 consumption with its inadequate inflow which leads to CO production. An active person, breathing air containing 5% CO has HbCO level of about 40% in 30 s. [7, 12].

However, in our sample car victims showed completely different results. Namely, in just one case with car victims HbCO concentration was high enough to cause death (over 50%), while in other cases (in 36% concentration was 11-50%) it indicated to vitality of the injuries sustained before the

fire of the traffic accident. The person was alive for certain period of time when it got engulfed in the flame, death was most commonly caused by brain contusion and it didn't occur instantly. In closed confines (car cabin) temperature of about 250°C occurs in 5-6 minutes [7] which rapidly causes burns. These result differ from those found in literature where it is stated that fire victims dying in closed automobiles uniformly exhibited HbCO levels exceeding 30%, and are conditioned by the fact that suicide by carbon monoxide from car exhaust – gas were not common in our country, but car accidents followed by fire were common (smuggling the gasoline) [9,13].

Ethanol is most commonly used and high proportion of cases of CO poisoning where ethanol was detected is not surprising. ([13,14, 15, 16]. Ethanol can potentiate the effects of CO such that lower levels of HbCO are associated with fatality. In our study average value of BAC was 0.06±0.01 g% (legal cut off in our country is 0.03 g%). BAC level in our example doesn't have statistically significant effect on HbCO concentration which differs from other studies [9, 15]. This could be explained with the specificity of our sample because analysis wasn't aimed toward inebriation in cases of high HbCO concentration, all the cases where HbCO was tested were analysed disregarding whether it was the cause of death. This study does not support the opinion that ethanol is key factor in fatal CO intoxication.

Many authors claim that heavy smokers can have HbCO saturation approaching 10% [2, 7]. Unlike in other research, HbCO concentration up to 10% in smokers and non smokers is equally present. One of the possible explanations for these findings could be that in our country there hadn't been any indoor smoking prohibitions until 2010 so non-smokers had been exposed to cigarette smoke-passive smoking; also our country is among the leading countries in the number of smokers (38% males, 30% female according to Ministry of health).

Persons with coronary artery disease cannot increase coronary blood flow when HbCO saturation is raised acutely [7]. In our study in the group with atherosclerosis and HbCO ranging from 21-50% (13%) CO intoxication could be considered as a cause of death. This is even more obvious when atherosclerosis is combined with smoking cigarettes, because these persons have died (in our sample) with HbCO from 21-50% (all other causes of death were excluded). In these cases HbCO concentration of over 50% wasn't even established because atherosclerosis and lung disease caused by smoking had predisposed individuals to the toxic effect of CO in lower concentrations [7].

By analysing burn degrees and HbCO we gained statistically reversed correlation between them, the lower the burn degree, the higher the HbCO concentration. (expB=-3.31; p=0.000) This is explained with that those persons died faster from high degree burns than was necessary for HbCO concentration to reach lethal levels. With charred bodies death comes as a result of other reasons before CO poisoning.

One of the uniqueness of CO poisoning in our area can be seen from analysing death by its means where by far the most common were accidental poisonings, whereas suicidal and homicidal were very rare, represented with 5%. CO poisoning as a suicide method is basically nonexistent in our

country, unlike USA [17] and Denmark [13], so we haven't had enough valid data for more thorough analysis. One of the characteristics of our sample is that there is high percentage of persons with psychiatric history in the group of those poisoned by CO (12%), but they mostly died accidentally, which is in agreement with the literature [18].

The present study has several limitations: other toxic gases were not analysed and representation of suicides and homicides was too low to make more precise conclusions [16, 19].

CONCLUSION

Characteristic victim of the CO poisoning is: older male with cardiovascular disease and psychiatric history, smoker, who died accidentally in closed space by open flame, with lower degree of the burns, with aspiration of soot, sober whereby women die with higher HbCO concetration. On the other hand, persons with low concentration of HbCO die of other causes of death (natural or trauma), mostly carbonised after death.

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