

Carbon Monoxide-Related Deaths from 1984 to 1993 in Vienna, Austria

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ABSTRACT: Carbon monoxide poisoning occurs frequently in industrialized countries. Between 1970 and 1978 in Vienna, the capital of Austria, carbon-monoxide-rich coal gas was replaced with natural gas. Despite this fact, people still die of unintentional carbon monoxide poisoning. The main purpose of this study was to determine the reasons for unintentional carbon monoxide-related deaths, and further to describe the epidemiology of these fatal poisonings in Vienna between 1984 and 1993. A secondary purpose was to investigate whether intentional carbon monoxide poisoning still plays a role among suicides as was the case up to the 1970s. For this purpose we analyzed carbon monoxide-related deaths in Vienna from 1984 to 1993, based on actual autopsy reports of postmortems performed at the Viennese Institute of Forensic Medicine. Deaths due to fire were excluded. The main reason for unintentional carbon monoxide-related deaths in Vienna between 1984 and 1993 was flueless gas-fueled water heating appliances, overused especially by old people during the cold period of the year. The frequency of unintentional carbon monoxide-related deaths in 1993 was almost as high as in 1984. A total of 53% of deceased persons were over age 60. Most fatal carbon monoxide poisoning occurred during the cold period of the year. Suicides decreased significantly during the investigation period. In 76% of these deaths car exhaust fumes were inhaled, especially by men. In conclusion, we recommend programs to prevent unintentional carbon monoxide-related deaths. These programs should especially target the elderly. Flueless gas boilers should not be overused. Furthermore, apartments should be aired sufficiently, even during the cold period of the year. Finally, homeowners should have gas appliances checked annually for proper functioning. It would be best to eliminate flueless gas-fueled water heaters as soon as possible.

KEYWORDS: forensic science, carbon monoxide, gas-fueled water heating systems, car exhaust fumes, fatal poisoning, suicides

Carbon monoxide is a colorless, odorless, tasteless, and non-irritating gas produced by incomplete combustion of organic materials. Common sources are car exhaust fumes, improperly maintained and ventilated gas heating appliances and smoke from all types of fires [1]. Carbon monoxide is also produced in humans during the catabolism of hemoglobin. Normal endogenous production of carbon monoxide is sufficient to saturate 0.4 to 0.7% of total hemoglobin at rest [2]. Smokers, however, may have much higher levels, reaching a maximum of 15% carboxyhemoglobin

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(COHb) [3]. Carbon monoxide has a high affinity for hemoglobin and interferes with oxygen transport to the tissues [4]. The symptoms of carbon monoxide intoxication depend on the concentration of this gas in the inspired air, the length of exposure, and the general health condition of the exposed person. Infants, the elderly, and patients with cardiovascular disease, anaemia, lung disease, and an increased metabolic rate are at greater risk [2,5]. Headache and dizziness are common early neurologic symptoms occurring at carboxyhemoglobin levels of 10% or greater [6,7]. Further symptoms may be chest pain, palpitations, visual disturbance, nausea, and diarrhea.

Carbon monoxide poisoning occurs frequently in industrialized countries [8-11]. In Vienna, the capital of Austria, there are presently 1,642,391 inhabitants who live in 746,760 households [12]. About 92% of these households are equipped with gas-fueled devices, like boilers, heaters, stoves, etc. In Vienna, carbon-monoxide-rich coal gas was replaced with carbon-monoxide-free natural gas between 1970 and 1978. However, despite this fact people still die of unintentional carbon monoxide poisoning.

The main purpose of this study was to determine the reason for unintentional carbon monoxide-related deaths, and further to describe the epidemiology of these fatal poisonings in Vienna between 1984 and 1993. A secondary purpose was to investigate whether intentional carbon monoxide poisoning still plays a role among suicides as was the case up to the 1970s.

Materials and Methods

For these purposes, actual postmortem reports on all deaths that were examined at the Institute of Forensic Medicine in Vienna between 1984 and 1993, were analyzed. Deaths for which carbon monoxide was listed as the underlying cause as well as a contributing factor were included in this retrospective study. In case of fire (flames, burns, explosives) data were excluded because the public health issues arising from such deaths are primarily related to preventing house fires [11]. Unintentional and intentional carbon monoxide-related deaths were analyzed regarding frequency, sex, age, COHb levels and sources. Census data of each year of the investigation period were used to calculate rates per 100,000 inhabitants of Vienna. Data of the Viennese Health Authorities regarding fatal accidents and suicides were used to calculate percentages of fatal carbon monoxide implication [12]. Blood samples for COHb determination were analyzed using a spectrophotometer (M4 QIII, Carl Zeiss).

Data were reported as mean \pm standard deviation (SD). We considered differences significant at $P < 0.05$. SAS 6.08[®] (SAS Institute Inc., Cary, NC) was used for numerical analysis.

Results

Study Subjects

From 1984 to 1993, 28,171 corpses were examined at the Institute of Forensic Medicine in Vienna. In 417 cases carbon monoxide poisoning was either an underlying cause of death or a contributing factor. 166 deaths were due to fire and therefore were excluded. Thus the actual post-mortem reports of 251 cases were analyzed for this study. In the deaths of 99 females and 101 males, carbon monoxide inhalation was unintentional (*n* = 200). The remainder—4 women and 47 men—committed suicide (*n* = 51).

Frequency of Fatal Carbon Monoxide Poisoning

The absolute figure of unintentional carbon monoxide-related deaths as well as the rate per 100,000 inhabitants increased to a peak in 1986 followed by a smooth decline (Table 1). In 1993, the percentage of carbon monoxide poisonings among fatal accidents was almost as high as in 1984. There was a strong association between unintentional carbon monoxide-related deaths and the cold period of the year from October to March (Fisher's Exact test: *P* < 0.01). The cumulative frequency of deaths in January was about sixteen times the frequency in July (31 vs 2 cases) (Fig. 1).

Intentional carbon monoxide poisoning also increased to a peak in 1986 and then significantly decreased over the years (regression analysis: *P* < 0.01) (Table 2). These suicides occurred more or less uniformly throughout the year (Fig. 1).

TABLE 1—Unintentional carbon monoxide-related deaths in Vienna (n = 200), 1984–1993. Institute of Forensic Medicine, Vienna, Austria.

Year	N	Rate ^a	% ^b
1984	16	1.18	2.3
1985	27	1.78	4.0
1986	29	1.92	4.6
1987	28	1.85	4.3
1988	14	0.91	2.3
1989	20	1.29	3.8
1990	19	1.21	3.4
1991	20	1.25	3.6
1992	13	0.80	2.6
1993	14	0.85	2.0

^aRates are per 100,000 inhabitants (census of each year).

^bPercentage of all fatal accidents in Vienna.

TABLE 2—Intentional carbon monoxide-related deaths in Vienna (n = 51), 1984–1993. Institute of Forensic Medicine, Vienna, Austria.

Year	N	Rate ^a	% ^b
1984	6	0.39	1.5
1985	8	0.53	2.3
1986	11	0.73	2.4
1987	4	0.26	0.9
1988	7	0.45	1.8
1989	6	0.38	1.6
1990	3	0.19	0.8
1991	3	0.18	0.9
1992	1	0.06	0.3
1993	2	0.12	0.6

^aRates are per 100,000 inhabitants (census of each year).

^bPercentage of all suicides in Vienna.

Sex and Age

Intentional carbon monoxide poisoning was strongly associated with the male sex (Fisher's Exact test: *P* < 0.001). A total of 92% of the people who committed suicide were men.

Unintentional deaths were of people who were significantly older than those who committed suicide (59 ± 24 vs 44 ± 17 (SD) years; Wilcoxon 2-sample test: *P* < 0.001). A total of 53% of unintentional carbon monoxide-related deaths occurred in people over age 60, but 53% of the people who committed suicide were between the ages of 30 and 49 at the time of death. The mean age of the victims of accidental poisonings was 55 years in 1984 and increased to 67 years in 1993. On the contrary, the mean age of the people who committed suicide decreased from 45 years in 1984 to 34 years in 1993, whereby both changes were not statistically significant.

COHb Levels

COHb levels in unintentional deaths were significantly lower than in suicides (62 ± 12 vs 71 ± 9 (SD) % COHb; Wilcoxon 2-sample test: *P* < 0.001).

In case of unintentional carbon monoxide inhaling, the older the victim, the lower the COHb level, which decreased by 0.16% per living year (regression analysis: *P* < 0.001).

Sources of Carbon Monoxide

In 157 unintentional deaths carbon monoxide derived from gas-fueled water heating appliances, of which 118 were without a flue.

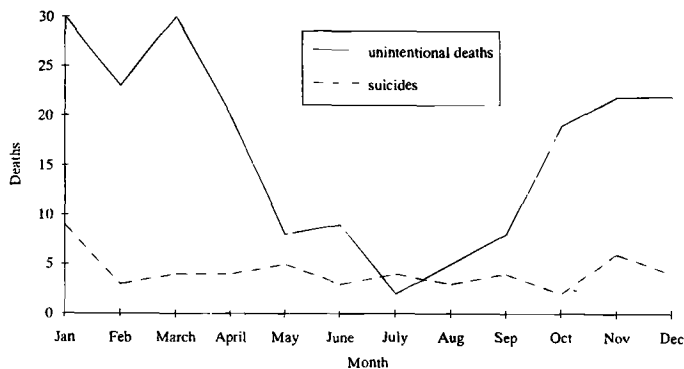


FIG. 1—Carbon monoxide-related deaths by month.

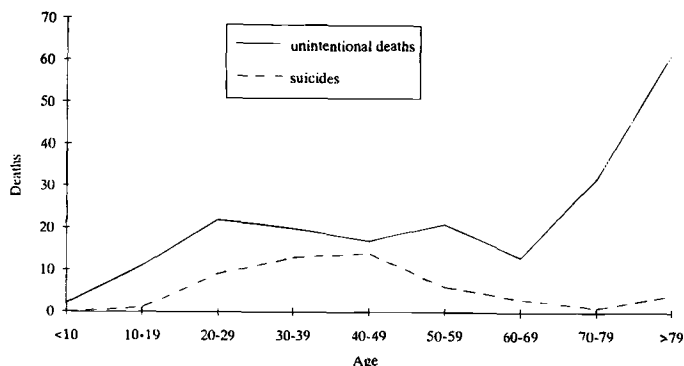


FIG. 2—Carbon monoxide-related deaths by age.

Only 36% of these boilers were defective. Fourteen fatal accidents were connected with the use of gas-fueled stoves and seven with the use of coal and/or wood in a domestic stove. One man died due to a malfunctioning stationary motor. In 21 cases, the gas source was not known to those conducting the post-mortem.

A total of thirty-nine suicides were due to inhaled car-exhaust fumes. Twelve persons killed themselves tampering with the gas appliances.

Discussion

The main reason for unintentional carbon monoxide-related deaths in Vienna between 1984 and 1993 was, as in other countries [9,13], flueless gas-fueled water heating appliances, overused especially by old people during the cold period of the year. Other reasons for carbon monoxide poisoning, for example motor exhausts, especially in association with stationary automobiles, coal or wood stoves were not so frequent in Vienna as in the United States of America [11,14]. It is estimated that there still are about 90,000 flueless boilers in use in Viennese households ("Vienna Gas"). The use of even a well-maintained gas water heater without a flue in a thoroughly insulated apartment, for other purposes apart from hand washing, can lead to carbon monoxide production [1,9,15]. In Vienna, the majority of these deaths occurred during the cold months of the year when rooms may not be aired sufficiently [16]. More than 50% of investigated cases of carbon monoxide-related deaths involved people who were over age 60 at the time of death. Old people with underlying cardiovascular disease are especially at increased risk if exposed to carbon monoxide [4,17]. These persons may have fatal complications already at COHb levels much lower than 60%, generally a lethal level in healthy people [2,18]. This relationship is supported by the finding that COHb levels decreased with age and that COHb levels in the people who committed suicide—who were significantly younger than unintentional deaths—were much higher.

In Vienna, unintentional carbon monoxide-related deaths occurred frequently enough to be disturbing. In 1988 the rate per 100 000 Viennese inhabitants was more than twice that of the United States of America [11]. Furthermore, there was no significant decrease in these deaths during the 10-year study period. In contrast, all fatal accidents declined in Vienna [12], but in 1993 the percentage of fatal carbon monoxide poisonings was almost as high as ten years before, despite consumer information campaigns by "Vienna Gas."

On the other hand, suicide by use of carbon monoxide significantly decreased during the investigation period. In general, the frequency of intentional carbon monoxide-related deaths almost diminished, wherever a switch to carbon-monoxide-free natural gas took place [19,20]. During the 1980s especially, males substituted the use of domestic gas for the use of car exhaust fumes as a suicide method [21]. These findings also related to Vienna. Nevertheless, the compulsory fitting of catalytic converters in all new cars in Austria since 1987 may have contributed to the remarkable decline in suicides [22].

In summary, we have shown that the main reason for unintentional carbon monoxide-related deaths in Vienna between 1984 and 1993 was flueless gas-fueled water heating appliances, overused especially by old people during the cold period of the year. Based on these findings we recommend programs to prevent unintentional carbon monoxide-related deaths. These programs should especially

target the elderly. Flueless gas boilers should not be overused. Furthermore, apartments should be aired sufficiently, even during the cold period of the year. Finally, homeowners should have gas appliances checked annually for proper functioning. It is also recommended to eliminate flueless gas-fueled water heaters as soon as possible.

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