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Accidental Poisonings Involving Carbon Monoxide, Heating Systems, and Confined Spaces

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ABSTRACT: Eleven incidents of carbon monoxide (CO) intoxication resulting in sixteen fatalities are reported. All of the cases involved heating systems as either the source or the means of distributing the CO. Blood samples were analyzed for ethanol and CO. Elevated blood CO saturations were found in 14 of the 16 victims while none of the victims had a blood ethanol concentration greater than 0.10% (w/v).

KEYWORDS: toxicology, carbon monoxide, poisons

The involvement of carbon monoxide (CO) in fire fatalities has been well documented. For example, in a previous study in Maryland [*1*], blood CO saturation ranged from less than 3 to 94% in 259 fire victims. Dominquez [*2*] studied aircraft accidents over a five-year period where approximately 10% of the victims died as a result of the ensuing fire after the crash. Birky et al [*3*] presented the results from analyzing samples obtained from victims of the MGM Grand Hotel fire. Carbon monoxide poisonings, intentional or unintentional, occurring in automobiles have also been reported. Baker et al [*4*] studied 68 accidental deaths that occurred in Maryland from 1966 to 1971 in which the CO saturation exceeded 30% in all but three cases. Baselt [*5*] investigated 41 fatalities from inhalation of automobile exhaust, finding CO saturations between 48 and 93%.

Although vapors from fires and motor vehicle exhausts represent the two most common origins of CO in fatal poisonings, such deaths are not limited to these sources. A malfunctioning space heater, furnace, or chimney may result in excess CO formation in houses, leading to toxicity and death of the inhabitants. Moreover, because of the lack of overt physical evidence linking CO to the incident being obvious, the real cause of death may be overlooked unless the scene is properly examined. In this paper, a series of cases involving faulty heating systems, with resulting toxicologic analyses, will be presented.

Representative Case Reports

Case 1

The victim, a 28-year-old white male, was found dead on the living room floor in the early morning by his father. At 5:30 p.m. on the previous day, the victim complained of fever and

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suffered a sudden onset of weakness and vomiting. At 12 midnight he was given Tylenol® and went to sleep on the living room floor because he kept falling out of bed. He died later that night. Both parents were extremely ill with an apparent diagnosis of "severe influenzal infection." The victim's parents had been treated for influenza at a local clinic and the victim had received a Swine Influenza innoculation two weeks before his death. The victim was transported to the Medical Examiner's Office and an autopsy was performed the next day. He was thought, at first, to have died as a result of the influenza. However, since CO poisoning and the "flu" may show similar symptoms, a CO determination was ordered and the amount was found to be in the lethal range. The local police were contacted and the house was evacuated. In addition to the victim's mother and father, two neighbors were in the house, having been there to help because of the occupants' "illness." All four persons were transported to the hospital and treated for CO poisoning.

The house was inspected and found to be heated with a 84 400-kJ (80 000-BTU) gas-fired hot air furnace. There was also an 113.5-L (30-gal), 47 805-kJ (45 000-BTU) gas-fired hot water heater installed in the basement adjacent to the furnace. Both of these appliances were vented into an 178-mm (7-in.) diameter Metalbestos® (double insulated) chimney. A test for CO was conducted in the atmosphere surrounding the top of the water heater and revealed 250 ppm of CO. The furnace showed 150 ppm of CO. A test of the heating duct outlets in the rooms on the first floors revealed 400 ppm of CO being emitted from each of these outlets. Both gas burning units were checked near the top. The chimney was removed and a blockage was discovered, a bird's nest that occupied a length of 305 mm (12 in.) in the 178-mm (7-in.) diameter pipe. Therefore, the fumes from the furnace and gas heater were restricted from leaving the chimney. The fumes then circulated back into the furnace and into the heating ducts, where they gained access to the interior of the house via the heat outlets in each room.

Case 2

The victims, a 68-year-old white male and his wife, a 67-year-old white female, were found in the first floor bedroom on a double bed. The male was dead, but the female was still alive and transported to a local hospital where she was treated for CO poisoning.

The heating system inspected consisted of a 63 300 kJ (60 000-BTU) space heater. This was allowed to burn for 5 to 10 min and a test for CO was conducted. The atmosphere near the rear of the heater revealed a CO concentration of 1000 ppm. When permitted to burn for an additional 15 min, the CO concentration in the first floor bedroom also reached 1000 ppm. The flame in the heater was burning approximately 102 to 152 mm (4 to 6 in.) in height with a predominantly yellow color indicating improper combustion. A test of the chimney and vents showed that the orifice restricting the incoming gas was 3.7 mm (0.147 in.) in diameter. This orifice was designed for use with natural gas; however, the gas supply was propane. The correct size orifice for the propane gas should be 2.18 mm (0.086 in.) in diameter. Propane is supplied at higher pressure than natural gas; hence, the use of the larger fitting fed excess gas to the flame. This inefficient combustion produced excess CO and led to high concentrations of CO in the house. Further investigation revealed that the installer inserted this improper orifice in the recently acquired space heater.

Case 3

The victim, a 67-year-old white male, was found dead in his apartment as a result of CO intoxication. Subsequent investigation by the local power company advised that a gas-fired hot water heater located in the basement of the apartment building was generating CO; the CO concentration in the air on top of the heater was 3000 ppm. This CO was emitted into the air ducts and the apartment. CO concentrations in the apartment ranged from 100 ppm in the bedrooms and kitchen to 500 ppm in the bedroom closet.

Case 4

The house was approximately 9 by 7.5 m (30 by 25 ft) and consisted of a single floor with four rooms and a bath. Located in the kitchen was an 113.5-L (30-gal) hot water heater, 39 035 kJ (37 000 BTU), vented to the chimney. A 47 805-kJ (45 000-BTU) gas space heater was located in the living room and contained a 101.6-mm (4-in.) vent opening in the back of the heater; however, the vent chimney pipe necessary to remove the fumes from the room was not installed.

Two victims were discovered in the house, a 17-year-old white male lying in the living room and a 3-year-old white male lying in the bedroom. When the victims were found, the unvented gas heater located in the living room was burning very high with a roaring sound. In addition, a regulator attached to a 4.5-kg (10-lbs) gas bottle located on the outside of the house near the living room was completely covered with ice. Examination of the exterior of the regulator revealed that it had been tampered with.

When the unvented heater was tested, a CO reading of 120 ppm was detected at the rear of the heater coming from the 101.6-mm (4-in.) opening after 10 to 15 min. This reading increased to 180 ppm after an additional 15 min. It was subsequently learned that the regulator permitted an excessive amount of gas pressure to enter the burner unit of the heater which caused further increased CO formation. Since the system was unvented, CO entered the room atmosphere.

Experimental Procedure

Carbon monoxide (CO) concentrations in air were determined using a Model 91850 Carbon Monoxide Indicator manufactured by the Mine Safety Safety Appliance Co., Pittsburgh, PA. Carboxyhemoglobin (COHb) saturation levels in blood were screened using a Model 182 CO-Oximeter (Instrumentation Laboratories, Inc., Lexington, MA). All COHb saturations greater than 12% were confirmed and quantitated using a gas chromatographic technique [*5*].

Ethanol analyses were performed using a Perkin-Elmer F-40 head space gas chromatograph.

Results and Discussion

Over a six-year period, eleven cases of accidental (nonfire, nonautomobile) intoxications have been documented and compiled. Table 1 lists the blood COHb saturation levels and blood ethanol concentrations of the victims. Of the 16 victims listed, 12 had COHb saturation levels greater than 50% which is sufficient to cause coma and death [*1,6*]. In two of the remaining four victims, COHb saturations were found that were toxic, but not generally considered lethal. However, Gettler and Freimuth [*7*] reported that of the 65 cases of CO intoxication they studied, approximately 9% died with a COHb saturation level below 50%. Moreover, Talbert and Muelling [*8*] attributed individual differences in the response to CO to three factors: (1) the rapidity of the intoxications, (2) the ability of the individual to tolerate the lack of oxygen, and (3) the presence of other drugs. In one of these cases, ethanol was found in the blood of the victim, the only case suggesting a drug which might cause an abnormal response to CO. The remaining two victims revealed COHb saturation levels in the normal range. One of these victims was found several days later and was badly decomposed; the other victim was found unresponsive in her house and treatment was attempted at the scene.

One difference between CO related fatalities involving fires and motor vehicles and the CO related fatalities discussed here is that the former are usually easily determined from the scene or other evidence while the latter are not. In situations where a furnace, space heater, or chimney may be at fault, CO may not be suspected and can often be overlooked especially when other medical explanations are apparent or the body is decomposed. Because of the criminal or civil litigation that most likely will follow, it is important not only to determine that CO was the cause of death, but to identify the specific source of the problem as well. In each of the rep-

TABLE 1—*Carboxyhemoglobin saturation levels and ethanol concentrations in blood of victims in cases of accidental carbon monoxide intoxication.*

Case	Victim(s)	Blood Carboxyhemoglobin % Saturation	Blood Ethanol, % w/v	Comments
1	28-year-old white male	47	negative	blocked chimney prevented CO escape
2	68-year-old white male	58	negative	improperly installed heater
3	67-year-old white male	66	negative	malfunctioning heater
4	3-year-old white female	63	negative	improperly vented heater
	17-year-old white male	67	negative	
5	83-year-old white male	60	negative	blocked chimney
6	40-year-old black male	63	negative	blocked chimney
	41-year-old black male	66	negative	
	69-year-old black female	64	negative	
7	65-year-old white female	77	0.08	car exhaust fumes distributed by a forced air furnace
	66-year-old white male	64	0.02	
8	43-year-old white female	51	0.01	blocked chimney
	50-year-old white female	37	0.05	
9	79-year-old white female	60	negative	blocked chimney
10	28-year-old white male	<12 (spleen)	0.04 (liver)	closed air shutter and improper adjustment on main burner
11	6-year-old black female	<12	negative	malfunctioning heater

resentative case reports, a different problem was detected by the scene investigators. For example, in the first case report, the gas burning units were operating properly but a blocked chimney prevented the toxic fumes from escaping. This is in contrast to the situation where the heater itself was malfunctioning, as in the third case.

One other aspect that makes these deaths different from fire and motor vehicle deaths is the role of ethanol in these fatalities. Baker et al [*4*] reported that in the 68 fatal unintentional CO poisonings in motor vehicles included in their study, 33 were positive for ethanol with 18 being greater than 0.10%. Over a 6-year period, 530 fire fatalities were studied in this Office [*9*]; 40% of the victims had positive blood ethanol with 85% of those victims having concentrations equal to or greater than 0.10%. On the other hand, although 5 of the 16 victims reported in this paper had a positive blood or liver ethanol, none of the concentrations were greater than 0.10%. This suggests that ethanol plays less of a role in this type of CO fatality than in the fire or vehicle types as would be expected. Since the cause of death was clearly established, no other toxicological analyses were performed in these cases. Therefore, no statement concerning the role of other drugs in these fatalities is possible.

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