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An unusual suicide by carbon monoxide intoxication: 91% HbCO saturation in a sealed setting

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ABSTRACT

Carbon monoxide (CO) is the most common lethal poison in every community yet studied. Accidental or suicidal CO poisoning has been reported as the most frequent manner of death. In the case we report here, a man was found dead inside his house with a strong smell of burning. The house presented no signs of effraction, and a lot of scotch tape was placed around the windows and doors edges as well as the keyholes to avoid any passage of air. Near the bed, there was an extinguished brazier with combusted carbon. After the external examination of the body a toxicological analysis was performed. The results pointed out 91% HbCO saturation in absence of signs of intermediate intoxication on the body or on the scene. This article aims to outline the importance of performing a multidisciplinary approach that includes an accurate crime scene investigation and a proper toxicological assessment, to evaluate the cause of death in cases of suspected CO inhalation suicide. The crime scene investigation together with the very high levels of HbCO saturation detected, suggest a possible correlation between time of exposure, source of CO, and saturation levels.

1. Introduction

Carbon monoxide (CO) is a colorless, odorless, tasteless, and non-irritating gas. It is produced in the occurrence of incomplete combustion of organic compounds such are gasoline, coal, wood, and natural gas. Common sources of CO are engines powering motor vehicles, faulty heating devices, industrial machines, generators, and pumps, but also fuel-burning heaters, ovens, and furnaces (Henn, Bell, Sussell, and Konda, 2013). Uncommon sources of CO are dichloromethane, for instance, used in aerosol propellants, or it can result from the combination of formic acid and sulfuric acid (Ernst and Zibrak, 1998; Hardy and Thom, 1994; Prahlow and Doyle, 2005). Carbon monoxide is the most common lethal poison in every community yet studied, accounting for critical care attention more than all other poisons combined, moreover accidental CO poisoning accounts for over half of all fatal poisoning annually occurring all over the world (Below and Lignitz, 2003; Gorman, Drewry, Huang, and Sames, 2003; Raub, Mathieu-Nolf, Hampson, and Thom, 2000).

With an annual death rate of 2.2 per 100,000 CO poisoning must be considered a world public health challenge (Braubach et al., 2013). Accidental and suicidal CO poisonings are widely reported as the most frequent manner of death (Byard, 2019; Janík, Ublová, Kučerová, and Hejna, 2017). Indoor environment is a common setting for fatal CO poisoning with about 60% of the deaths occurring at home (Clifton, Leikin, Hryhorczuk, and Krenzelok, 2001). Accident-related intoxications were reported more frequently in the winter months, probably due to heating means, while suicide poisonings seem to be equally distributed throughout the year (Yurtseven et al., 2015).

Unintentional CO poisoning has been reported in six young methamphetamine, cocaine and cannabis or opiates addicts staying in an apartment with a gasoline-powered generator (Marc et al., 2001). Waterpipe tobacco smoking (hookah, narghile) has also been associated to the risk of CO poisoning (Soule, Lipato, and Eissenberg, 2015; Underner, Perriot, Peiffer, Dewitte, and Jaafari, 2020). A Danish longitudinal study on 121 cases of deliberate self-poisoning revealed that almost two-thirds were caused by legal drugs and 17% by carbon monoxide (Hansen, Jespersen, and Kristensen, 2006). A 10-year retrospective observational study on patients hospitalized in Wroclaw due to intoxication by drugs or other xenobiotics revealed that suicide was the leading cause of death including CO poisoning (Sawicka, Kartuszyńska, Kuczyńska, and Piwowar, 2019).

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Fig. 1. Detail of scotch tape around window.

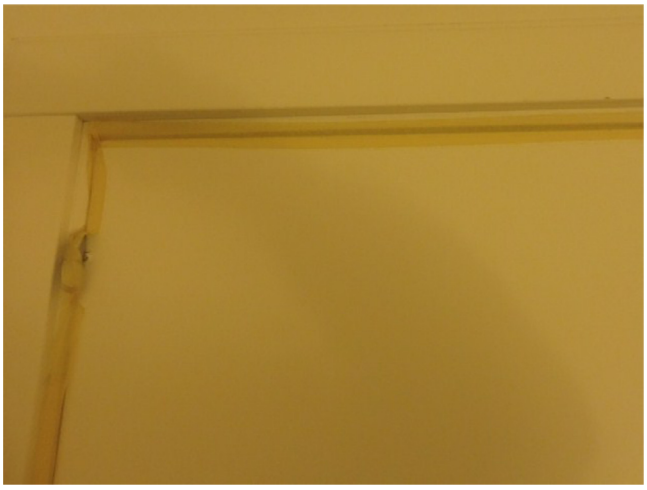

Fig. 2. Detail of scotch tape around door.

In this paper, an unusual case of suicide by CO poisoning is reported. This article aims to outline the importance of performing a multidisciplinary approach that includes an accurate crime scene investigation and a proper toxicological assessment, to assess the manner and cause of death in cases of suspected CO inhalation.

2. Case report

2.1. Crime scene investigation

In January 2020, in a little town in Southern Italy, a man was found dead inside his house on the first floor of a building. Firefighters reached first the place, after having being called due to the suspect absence of the man from his workplace; they entered the house forcing the door and finding the man lying on his own bed. The apartment rooms were completely dark, and there was a strong smell of burning.

The judicial authority was then alerted, and the police arrived at the place to perform a preliminary crime scene investigation. The house presented no signs of effraction, the examination of doors and windows allowed to detect that they were sealed from the inside. The public prosecutor then appointed a forensic pathologist to evaluate the case. The inspection of the rooms pointed out the absence of signs of a fight, furnishings were intact, the money and valuables were in place. A lot of scotch tape was placed around windows and doors edges, as well as keyholes to avoid any passage of air (Fig 1, 2, 3). Near the bed, there was an extinguished brazier with combusted carbon and an opened carbon case on the floor (Fig 4). Few meters away there was also a ladder with, a lighter, and the mentioned scotch tape on a rang.

2.2. External examination

After the primary evaluation on the scene, we continued our analysis directly on the corpse of the deceased. The man, apparently 60 years old, was in the bed covered by 2 blankets, wearing a pajama and presenting cherry-red hypostasis at the rear portions of the body, and red coloration of the nails. A deeper analysis showed that there was not any kind of traumatic lesion, except 2 small rounded excoriations of 3 × 2 cm in the dorsal region probably deriving from an exploded blistering lesion. When the body was moved, percolation of liquid material from the buccal cavity was detected. The cadaveric rigidity resulted in resolution and the rectal temperature detected was 23.2°Celsius compared and ambient temperature was 13.7°Celsius. Following the preliminary body evaluation, it was taken to the local Institute of Legal Medicine for further thanatochronological analyzes.

Fig. 3. Detail of scotch tape around edge and keyhole.

The weight was 80.9 kg, the length of 179 cm. The hypostases were scarcely pale on acupressure. The examination aimed at finding traumatic and / or violent injuries did not reveal any noteworthy elements. Peripheral and central blood was taken to carry out toxicological tests.

2.3. Toxicology assessment

We performed:

- blood alcohol quantification using headspace gas chromatography with FID detector technique;
- narcotics and / or psychotropic substances detection, using immunochemical technique and gas chromatography with mass spectrometry;
- carboxyhemoglobin (HbCO) quantification, using UV-Vis spectrophotometry.

The first level immunochemical screening of the main drugs of abuse was negative based on the following cut-offs: Amphetamine (500 ng/ml); Cannabinoids 50 ng/ml; Cocaine 300 ng/ml; Ecstasy 500 ng/ml; Methadone 300 ng/ml; Opiates 300 ng/ml; Methamphetamine 500 ng/ml). The blood alcohol test yielded the following result: Ethyl alcohol 0.026 g /L

Fig. 4. Detail of brazier.

2.4. The cause of death

The results of lab tests were negative for alcohol and drug intake and showed a HbCO saturation level of 91%. Given this data and the absence of traumatic lesions, the cause of death was attributed to fatal CO inhalation. Moreover, the evidence coming from the crime scene investigation clearly indicated the suicidal nature of the event. Considering the numerous evidence available, the judicial authority decided not to order the autopsy because the cause of death was considered clarified, and the modality clearly compatible with an autonomous action by the victim.

3. Discussion and Conclusion

Carbon monoxide is physiologically produced at a rate of 0.4mL/h by normal metabolism so that everyone has a minimum percentage of CO in the blood, about less than 5% of the saturation concentration in non-smoking people and about 10% in people working or living in environments with high levels of atmospheric pollution (Karapirli et al., 2013).

Immediately absorbed through the lungs, CO binds to hemoglobin as carboxyhemoglobin (HbCO) causing a leftward shift of the oxygen-hemoglobin dissociation curve with a linear correlation between the inspired level of CO and arterial level of HbCO (Bauer and Pannen, 2009). Carbon monoxide has a very high affinity for heme proteins, especially for hemoglobin that has an affinity for CO that is 218-fold greater than for oxygen (Hess, 2017; Kao and Nañagas, 2006; McBay, 1973). Moreover 10 to 15% of absorbed CO binds to other iron-containing metalloproteins such myoglobin and the mitochondrial cytochrome a3 reducing the production of ATP (Thom and Keim, 1989).

This metabolic reaction induces different and non-specific symptoms in a first phase reversible. If the level of carboxyhemoglobin increases, the process becomes irreversible causing hypoxia that causes death from multiorgan suffering (Table 1) (Heath and Byard, 2019).

Hypoxia is acknowledged as the main mechanism in CO poisoning deaths though in recent years there has been evidence that an important role in CO toxicity is attributable also to the increased free radical-mediated or ROS-mediated cellular injury (Akyol et al., 2014). The most vulnerable organs to CO-induced hypoxia are the heart and the brain, because of their high metabolic rate. Consequent cardiac dysfunction including arrhythmias and myocardial ischemia have also been reported in fatal and non-fatal cases (Garg et al., 2018). The myocardial damage and the consequent decreased cardiac output can also contribute to hypoxic-ischemic brain injury, neuropsychiatric sequelae (Abdel Salam, Elawady, Khater, Eweda, and Abd El Moneam, 2021) as well as delayed neurological sequalae (Del Moral-Barbudo, Blancas, Ballesteros-Ortega, Quintana-Díaz, and Martínez-González, 2020). Recent studies suggest that CO poisoning can cause endothelial dysfunction and hypercoagulability leading to deep vein thrombosis and pulmonary embolism (Chung, Lin, and Kao, 2015).

Table 1
Levels of HbCO saturation (%) and related symptoms.

HbCO saturation (%)	Symptoms
< 1	- normal range (due to endogenous production)
< 10	- smoker's blood (no symptom)
10–20	- headache, fatigue, ear ringing
20–30	- headache, weakness, nausea, vomiting
30–40	- severe headache, dizziness, nausea, vomiting
40–50	- syncope, confusion, increased respiration and heart rate
50-60	- coma, convulsions, depressed respiration
60–70	- coma, convulsions, cardiopulmonary depression, often fatal
> 70	- respiratory failure, death

The detection of cherry-red hypostasis at the external examination of the body must be considered suggestive rather than definitive of CO poisoning (Ruas, Mendonça, Real, Vieira, and Teixeira, 2014). The presence of cherry-red lividity is enhanced due to the stasis of superficial cutaneous vessels because of the vasodilatation caused by CO.(24) Ruas et al. reported the presence of cherry-red lividity only in 37.5% of the cases with positive toxicological analysis for HbCO with no correlation between the color of the hypostasis and HbCO saturation (Findlay, 1988). Erythematous lesions and cutaneous blisters can be found both in hospitalized patients and in fatal cases, either in compressed and in non-compressed areas, but are non-specific (Dolan, 1985).

The lethal concentration of CO can be achieved in less than 10 minutes in a confined room (Ernst and Zibrak, 1998). As exposure increases, more pronounced and severe symptoms occur.

Symptoms are nonspecific and range from headache and vomiting to seizures, coma, and cardio-respiratory arrest (Kao and Nañagas, 2006; Prockop and Chichkova, 2007). Levels of HbCO exceeding 50% are usually considered potentially lethal, however underlying medical conditions such as cardiovascular disorders, chronic obstructive pulmonary disease (COPD), or anemia, or the presence of alcohol can significantly low this percentage (Bauer and Pannen, 2009). People who died from inhalation of motor vehicle exhaust gases usually have a value of blood CO saturation concentration of at least 60% or more (McBay, 1973).

The value of 91% Hbco saturation we detected in the present case was the highest among the 55 cases in which HbCO assessment was requested at the Institute of Forensic Medicine in Bari.

Among these cases, 16 are those in which the cause of death was eventually identified in a carbon monoxide intoxication with an average HbCO saturation of 57.12%.

Moreover, to confirm the exceptionality of this data we reviewed two different databases (PubMed and Google Scholar) that were questioned using the main keyword *"carbon monoxide poisoning"* that was crossed with *"HbCO saturation"*. The value detected in the present case was one of the highest ever reported.

In conclusion, a multidisciplinary approach is mandatory to assess the cause and the manner of death in cases of suspect fatal CO inhalation. The lack of signs on the body (e.g. contusions or excoriations by convulsions) or on the scene (e.g. traces of vomiting) suggest that the lethal HbCO saturation levels have been reached in a very short time.

Moreover, the particular setting in which the event of the present case took place together with the very high levels of HbCO saturation, detected suggests a possible correlation between time of exposure, source of CO, and saturation levels.

CRediT author statement

Davide Ferorelli, Gabriele Mandarelli: Conceptualization; Methodology, Investigation

Lorenzo Spagnolo, Federica Misceo: writing—original draft; writing—review and editing

Giuseppe Strisciullo: Formal Analysis, Data curation

Lorenzo Polo, Biagio Solarino, Alessandro Dell'Erba: Project Administration, Supervision, Validation

All authors have read and agreed to the published version of the manuscript.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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