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Original communication

# Carbon monoxide poisoning as a cause of death and differential diagnosis in the forensic practice: A retrospective study, 2000–2010

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ABSTRACT

This study presents the epidemiology and the *postmortem* forensic aspects in cases with a carboxihemoglobin (COHb) analysis, from autopsies performed at the Forensic Pathology Department of the Centre Branch of the National Institute of Legal Medicine and Forensic Sciences of Portugal. Between January 2000 and December 2010, 69 COHb analyses were requested in our institution. In approximately 70% of the situations, circumstantial information included a Carbon Monoxide (CO) source at the death scene. More than half of the cases presented thermal lesions, cherry-red lividity, and cherry-red blood and viscera coloration were found in, approximately, 30% of the cases. Fourteen cases were recorded as CO poisonings. The highest number of poisonings occurred in 2000, with most of the cases in winter (53.8%), in 51–60 years-old male individuals. 69.2% of the poisonings were accidental and the remainder were suicides, being fires the most frequent sources of CO (38.5%). Cherry-red lividity was present in 61.5% of the cases, and all of them presented cherry-red blood and viscera coloration. Older individuals and those with thermal lesions presented lower COHb levels, and politrauma was the most frequent cause of death among the negative cases. It is possible to conclude that the forensic aspects of CO poisonings interact in a complex way, and differential diagnosis is not straightforward. This study also emphasizes the role played by public prevention campaigns and improvement of heating appliances in reducing the number of accidental CO poisonings, and the importance of preventing urban and forest fires, the major source of CO among us.



## 1. Introduction

Carbon monoxide (CO) is a product resultant of the incomplete organic materials combustion. Natural sources of CO include forest fires and volcanic eruptions, even though it is mainly produced by human activity.[1] Automobile exhaust fumes, charcoal briquettes in confined spaces, and defective or improperly ventilated gas heating appliances are common sources of CO. Although nontoxic natural gas is now the primary source of domestic energy, its combustion with an insufficient supply of oxygen generates CO, with its own deleterious effects.[2] CO also results from heme catabolism, and has recently been recognized as a neurotransmitter.[3] Endogenous production and environmental exposure to CO account for carboxihemoglobin (COHb) baseline levels of less than 1–3% in non-smokers, and up to 10% in smokers.[1,4] CO is odorless, colorless and tasteless, not easily detected by an exposed person, and since it has approximately the same air density, it can easily spread through confined spaces.[2] The general toxicity mechanism of CO depends on its exceptional affinity for hemoglobin, which is 200 times higher than that of oxygen, resulting in tissue hypoxia. Today it is recognized that CO may have a direct cellular toxicity.[1,4] Depending on the concentration of the gas in the air, the length of exposure and health conditions, CO effects can range from mild cardiovascular and neurobehavioral symptoms at COHb levels of less than 15–20%, to unconsciousness and death. Children, patients with

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coronary and lung disease and the elderly, can be more susceptible to a CO intoxication.[4–6]

In forensic practice, CO-related deaths can mainly result from accidents or suicides, being homicides very rare. Risser and Schneider (1995) reported that, in 417 CO-related deaths, over a ten year study in Vienna, the majority of cases were accidents, higher in winter months.[6] These findings are similar to those of Homer et al. (2005) in Cleveland, USA and Ait El Cadi et al. (2009) in Morocco.[7,8] Scene investigation often provides circumstantial indications of CO poisoning, and autopsy usually follows. Characteristic pathological findings include: cherry-red or bright pink livor, and bright cherry-red coloration of blood, musculature and viscera, consistent with levels of COHb higher than 30%.[9,10] They are important forensic clues to determine the cause of death, which is established after determining COHb levels higher than 50–60%, in *postmortem* blood samples. However, it is not easy to establish the role of CO as the cause of death, and the interpretation of lower or negative COHb levels in victims with concomitant morbidity can be difficult, namely when excluding natural death, since delayed CO-related death cases with suggestive circumstances may be present with negligible COHb in blood.[11] On the other hand, cherry-red livor can be absent[12] or result from body refrigeration and/or cyanide poisoning.[13] Increasing public awareness of the dangers of CO poisoning, improved the safety of heating and cooking appliances, and gas emission controls in transports may have been responsible for the decline in the number of unintentional CO-related deaths. Nonetheless, CO poisoning remains involved in over one half of all fatal poisonings worldwide, yearly.[4,5]

The purpose of this study was to investigate the epidemiology and forensic aspects related to CO poisoning, in cases with *postmortem* COHb analysis, from autopsies performed at the Forensic Pathology Department of the Centre Branch of the National Institute of Legal Medicine and Forensic Sciences of Portugal (INMLCF), between 2000 and 2010.

## 2. Material studied

Autopsy reports of all deaths performed at the Forensic Pathology Department of the Centre Branch of the National Institute of Legal Medicine and Forensic Sciences of Portugal (INMLCF), between January 2000 and December 2010, were reviewed. Data material consisted of 69 autopsy reports referenced to have a *postmortem* carboxihemoglobin (COHb) analysis request. COHb analyses were performed in *postmortem* blood samples, at the Forensic Toxicology Department of the Centre Branch of the INMLCF by a molecular absorption spectroscopy methodology.[14] Assessment of the examination protocols was conducted by means of a tabular database according to the following criteria: year, month, season of the year (January, February and March were considered winter months; April, May and June, spring months; July, August and September, summer months and October, November and December, autumn months), age, gender, occupation, underlying disease, medico-legal etiology, source of CO, cause of death, autopsy findings (lividity, thermal injuries, coloration of blood and viscera), and toxicological analysis results. These variables were studied, and relevant data was submitted to numerical analysis, using SPSS (Statistical Package for Social Sciences).

## 3. Results

### 3.1. COHb analysis requests

#### 3.1.1. Year, month and season distribution

Between January 2000 and December 2010, 69 *postmortem* COHb toxicological analysis were requested and performed at the Centre Branch of the INMLCF. As presented in Fig. 1, the number of COHb analysis requests was higher in 2005, with 15 cases (21.7% of all requests). The years 2002 and 2006 presented the lowest number of requests, 2 (2.9%). COHb analysis requests were more frequent in March (13 cases, 18.8%) and winter (24 individuals, 34.8%) (Fig. 1).

#### 3.1.2. Gender, age and occupation

A COHb analysis was requested in 44 male individuals (63.8%) and 25 female individuals (36.3%). The >70 years-old age group presented the highest number of COHb analysis requests (22 cases, 31.9%), and the age groups 11–20 years-old and <10 years-old were the groups with the lowest requests number (1 request – 1.4% and 2 requests – 2.9%, respectively) (Fig. 2). In 75.4% of the requests (52 cases), the information about the occupation of the deceased wasn't, *per se*, justification of a CO poisoning suspicion, whether because it was unknown (50.7% of all requests) or because the occupation wasn't associated to an increased risk of CO poisoning (24.6%). In 4 (5.8%) cases, the individual was a fireman, and in 13 (18.8%), a pensioner (Fig. 3). Among the cases not associated to an identifiable source of CO but with COHb analysis request, 4 (19%) individuals were pensioners, and in 17 (81%), the occupation was unknown or not associated to an increased risk of CO poisoning.

#### 3.1.3. Etiology and source of CO

The medico-legal etiology indicated *natural death* in 11 requests (15.9% of all cases). Fifty individuals (72.5%) presented a

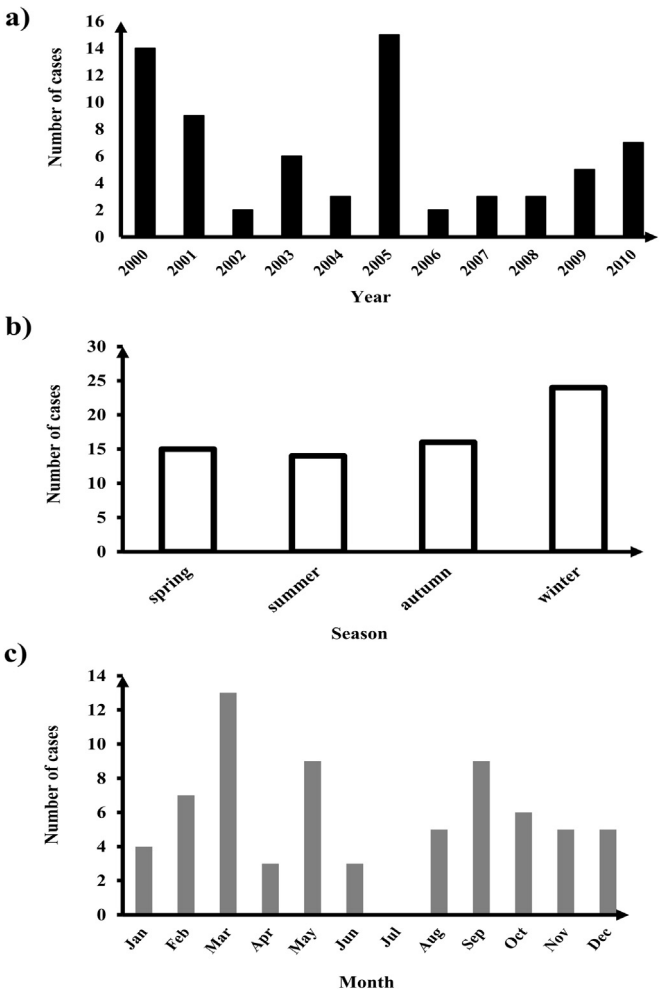


**Fig. 1.** COHb analysis requests distribution by year [a)], season [b)] and month [c)].