

Prevalence of Acute Myocardial and Brain Toxicity in Emergency Department Patients Exposed to Carbon Monoxide

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Abstract

Introduction: Due to its severe toxicity, carbon monoxide poisoning is an emergency that leads to cardiac and brain involvement, and emergency physicians should aim to master this diagnosis. This study is intended to describe the expected prevalence of these severe toxicities in the emergency department. **Materials and Methods:** A retrospective cohort of consecutive patients over 16 years of age presenting with carbon monoxide poisoning to the emergency department of the Hospital Universitario Austral, Argentina, during the period from January 2018 to June 2022. The prevalence of myocardial and brain toxicity was assessed regarding percentage, continuous variables with mean and standard deviation, categorical variables with percentage and absolute frequency. Positive findings of acute neurological toxicity included seizures, syncope and coma, while cardiovascular toxicity encompassed acute myocardial infarction (MI) diagnosed by electrocardiogram or elevated troponin levels, arrhythmias, and the development of pulmonary edema/congestive heart failure (CHF) confirmed by chest X-ray with suggestive signs or clinically compatible symptoms. Patients were followed-up for 90 days to estimate hospitalization and mortality. **Results:** A total of 67 patients were evaluated; 44.77% of them were males with a mean age of 38.5 ± 14.97 years. The prevalence of acute myocardial toxicity was 7.46% (n: 5). Among these patients, 3 had overweight as a risk factor, and 3 showed ECG abnormalities with negative T-waves. The prevalence of acute brain toxicity was 8.9% (n: 6). In total, 37% (n: 25) of patients met the criteria for hyperbaric oxygen therapy, of which 32% (n: 8) underwent more than one session. A total of 7.46% of patients (n: 5) required hospitalization. Mortality at 90 days was 0%. **Conclusion:** Among the patients who presented to the emergency department, the prevalence of acute myocardial toxicity was 7.46% (n: 5), which is lower than

the prevalence reported in other studies to date. The prevalence of acute brain toxicity was 8.9% (n: 6), and there are no studies describing the prevalence of acute brain toxicity in the emergency department to date. There were no fatalities in our series.

Keywords

Carbon Monoxide Poisoning, Myocardial Toxicity, Brain Toxicity, Hospital Universitario Austral

1. Introduction

Carbon monoxide poisoning is a condition that causes hundreds of deaths each year, typically as a result of accidental indoor exposure to various sources of incomplete combustion of carbon in burnable materials (wood, gas, kerosene, alcohol, diesel, gasoline). This can be fatal in poorly ventilated environments. Odorless, colorless, and non-irritating to the respiratory tract, its effects are often insidious [1] [2]. In severe cases, carbon monoxide toxicity leads to cardiac and brain involvement, and emergency medical specialists should try to be more skilled at diagnosing. This study aims to describe the expected prevalence of these conditions in the emergency department.

In the USA, 50,000 annual visits to the emergency department due to carbon monoxide poisoning have been described [3] (while there are 12.2 million annual visits for abdominal pain and 6.5 million annual visits for chest pain [4]).

The Hospital Universitario Austral located in Pilar, Buenos Aires, Argentina, receives 20,000 monthly visits to the emergency department, out of which 68% are for the adult department. An average of 10 patients is hospitalized per day. In the 2018-2022 period, the hospital received 67 visits for carbon monoxide poisoning.

2. Materials and Methods

During the period of January 2018 to June 2022, 278 patients that presented to the toxicology department for outpatient follow-up for carbon monoxide poisoning were included in the study. A total of 278 electronic medical records were reviewed. Patients who previously visited the emergency department of the Hospital Universitario Austral were included for analysis. Patients under 16 years of age, those who have sought care at an emergency department outside our hospital, and follow-up consultations were excluded from the study. In total, 67 patients were included for analysis. Of these, 44.77% were males with a mean age of 38.5 years, with a standard deviation of 14.97.

The prevalence of present clinical symptoms (headache, dizziness, weakness, nausea, drowsiness, confusion, shortness of breath and visual disturbances) was analyzed.

We also assessed whether carbon monoxide had been measured, and values higher than 3% in non-smokers and higher than 10% in smokers were considered positive.

Potential sources of carbon monoxide included: gas water heater, gas hot water tank, wood burning stove, gas heating stove, wood fireplace, boiler, brazier, gas oven, car and motorcycle internal combustion engine, and fire incident.

The prevalence of severe neurological and myocardial toxicity was analyzed in the population. Severe neurological toxicity was defined as seizures, syncope and coma. Severe cardiovascular toxicity was identified by acute MI (myocardial infarction) confirmed by electrocardiogram or elevated troponin levels, arrhythmias, and pulmonary edema/CHF (congestive heart failure).

All patients (100%) had ECG and troponin levels measured at the emergency department.

Based on the institutional protocol, the criteria for prescribing hyperbaric oxygen therapy were:

- 1) Neurological disorders: transient or prolonged loss of consciousness, seizures and neurologic deficit.
- 2) Cardiovascular disorders: chest (precordial) pain, elevation of cardiac enzymes, ECG abnormalities. Patients with a history of acute heart disease or heart disease exacerbated by the poisoning are specially taken into account.
- 3) Severe acidosis.
- 4) Asymptomatic patient with COHb > 20%.
- 5) Pregnant women, regardless of COHb levels [5].

We calculated the prevalence of hyperbaric oxygen therapy, the need of more than one (1) session, hospitalization and 90-day mortality.

The EpiDat system was used for data analysis using the statistical Fisher's exact test.

3. Results

During the period from January 2018 to June 2022, 67 patients were included for analysis; 44.77% were males with a mean age of 38.5 (standard deviation: 14.97).

In total, 83% of patients (n: 56) had some form of symptoms (headache, dizziness, weakness, nausea, drowsiness and confusion, shortness of breath and visual disturbances); 98% (n: 66) were positive for carbon monoxide on blood tests.

The type of exposure in descending order was: 21.2% boiler, 13.6% gas water heater, 10.6% fire incidents, 10.6% gas heating stove, 10.6% brazier, 7.6% stove (not specified), 4.5% oven, 1.5% burner, and 19.8% others (see **Figure 1**).

The prevalence of severe myocardial toxicity (defined as acute MI) confirmed by electrocardiogram or elevated troponin levels, arrhythmias and pulmonary edema/CHF was 7.46% (n: 5). Three (3) of the patients had cardiovascular risk factors (overweight in all 3 cases). This leads to a prevalence rate of 32 (CI 95%: 8 to 125), p: 0.0002 which means that overweight did not prove to be a risk fac-

tor that increased the risk of carbon monoxide poisoning in our study. The prevalence of ischemic ECG changes was 4.47% (n: 3); in all 3 cases the findings showed negative T-waves in one area of the heart (lateral wall in 1 case and inferior wall in the other 2). The prevalence of severe brain toxicity (seizures, syncope, coma) was 8.9% (n: 6). Only one patient presented both toxicities. Thirty-seven (37) percent of patients (n: 25) were treated in a hyperbaric oxygen chamber, and 32% (n: 8) of them received more than one session (see **Figure 2**).

Among patients with cardiac toxicity (n: 5), 80% (n: 4) had elevated levels of cardiac biomarkers (high-sensitivity cardiac troponin T), values higher than 14 pg/ml being considered positive while the only patient without elevated cardiac enzymes was at the upper limit of normal (13 pg/ml) (see **Figure 3**).

None of the patients with brain damage had risk factors. Among patients with brain toxicity, 16.7% had seizures (n: 1) and 83.3% syncope (n: 5) (see **Figure 4**).

A total of 7.46% (n: 5) required hospitalization. The 90-day mortality was 0%.

Type of exposure

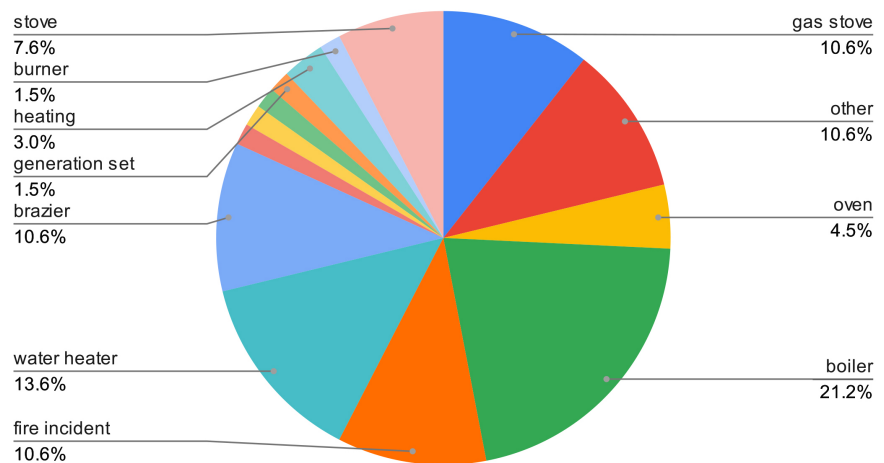


Figure 1. Type of exposure in patients with carbon monoxide poisoning who visited the emergency department of the Hospital Austral during the 2018-2022 period.

Distribution of total toxicity

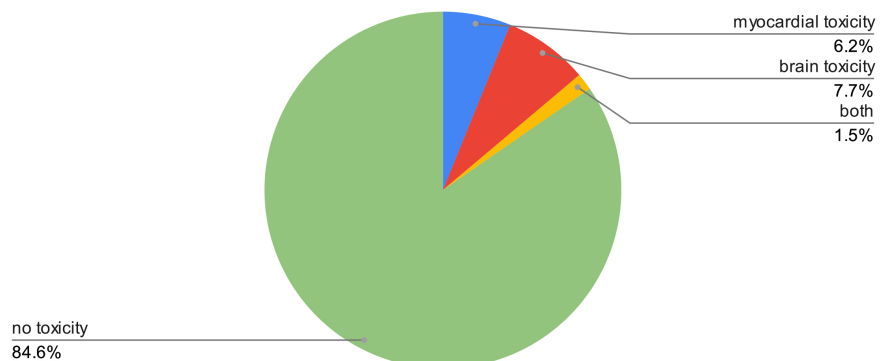


Figure 2. Percentage prevalence of acute myocardial and brain toxicity in patients with carbon monoxide poisoning who visited the emergency department of the Hospital Austral in the 2018-2022 period.

Troponine on arrival (pg/ml)

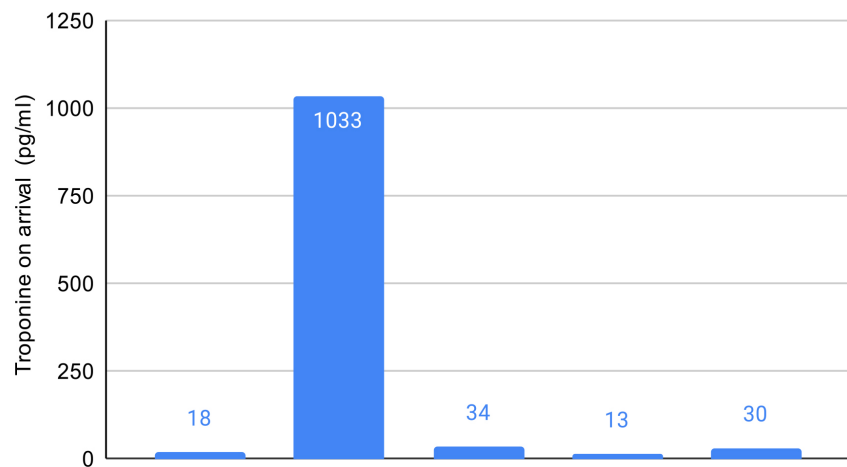


Figure 3. Values of troponin in pg/ml in patients with cardiac toxicity due to carbon monoxide poisoning who visited the emergency department of the Hospital Austral in the 2018-2022 period.

Neurological toxicity (n: 6)

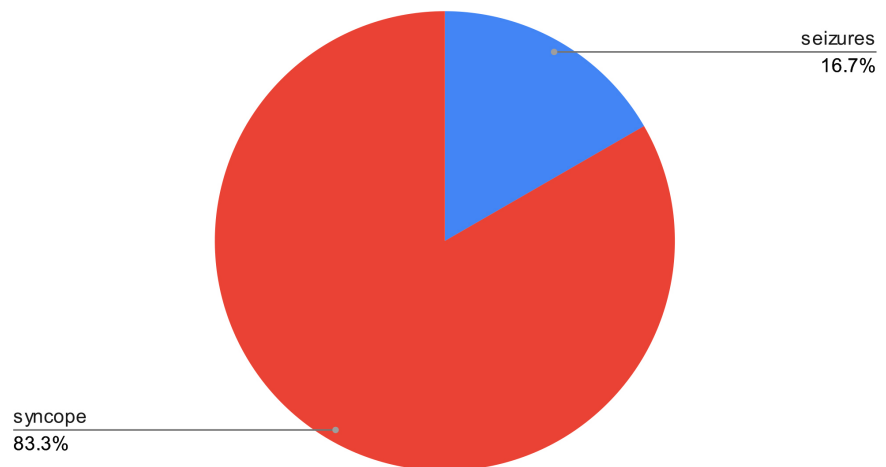


Figure 4. Distribution of severe neurological toxicity symptoms in patients with carbon monoxide poisoning who visited the emergency department of the Hospital Austral in the 2018-2022 period.

4. Discussion

Cardiovascular toxicity of carbon monoxide is well documented. In 2005, Satran, D. *et al.* found elevated TnT I and CPK in 37% of patients (n: 230). The population studied was mainly composed of males (72%) aged 47.2 (19 - 91 years) with a higher percentage of cardiovascular risk factors (17% had diabetes, 23% hypertension, 56% were smokers, 7% had a history of previous acute myocardial infarction, 3% had underwent bypass surgery). A total of 30% presented ECG changes and 16% had no changes. This led to the requirement of a baseline ECG and serial troponin measurements in patients with carbon monoxide poisoning [6].

Regarding ECG changes, 41% of patients presented sinus tachycardia, and 16% were normal. Out of the 30% with ischemic changes, 26% showed T-wave changes or ST depression, and 4% exhibited ST segment elevation.

Of the 183 patients having biomarkers measured, 44% (n: 81) presented changes defined as CK-MB \geq 5 ng/ml or troponin I \geq 0.7 ng/ml.

Our prevalence study found a substantially lower incidence of cardiovascular toxicity (7.46% instead of 44%), with a significant difference in patient database collection: our database comes from outpatient toxicology follow-up data while in this study it is based on patients requiring hyperbaric oxygen therapy in the Hennepin County Medical Center. The indications for hyperbaric oxygen therapy included severe toxicity.

The same study describes considerably interesting data regarding the prevalence of brain toxicity: 81% of patients (n: 187) had coma and 50% of them required intubation (n: 116), which is also higher compared to the prevalence of 8.9% found in our study.

Long-term (chronic) carbon monoxide poisoning is also well-documented but, to our understanding, this is not the case for its severe toxicity.

A South Korean retrospective cohort study published in June 2021, analyzed the HIRA (National Health Insurance System) database and searched the national health system from 2012 to 2018, reaching a remarkably higher n: 26; 778 patients with a mean age of 44.36 (\pm 17.32), 39.61% of women: (n: 7.415), the long-term CNS toxicity was evaluated and a prevalence of 86.2% (n: 18.720) was found, also higher than our finding of 8.9%. A total of 1,391 (7.43%) patients had to be admitted to the intensive care unit. A relevant difference with our analysis is that this study excluded patients with a history of CNS conditions. Significant neurological toxicity included onset and maintenance insomnia (n: 701; 3.74%), tensional headache (n: 477; 2.55%), anoxic brain injury (n: 406; 2.17%). The standardized incidence ratio (SIR) for the likelihood of developing CNS toxicity was studied in patients requiring ICU admission and it was found that the incidence was significantly higher in this subgroup: 2.25 (CI 95% 2.07 - 2.44), $p < 0.05$. Specifically, significant signs were onset and maintenance insomnia (SIR 1.61; CI 95%: 1.52 - 1.71), tensional headache (SIR 2.41; IC 95%: 2.23 - 2.61), anoxic brain injury (SIR 58.76; CI 95%: 53.95 - 63.88) and postherpetic neuralgia (SIR 1.94; IC 95%: 1.70 - 2.20). Also, the condition developed significantly earlier (diagnosed 68 days earlier in patients requiring ICU admission compared to 234 days in those not requiring ICU), 350 days compared to 560 days for post-zoster neuralgia, and 260 days instead of 469 days for sleep disturbances [7].

4.1. Strengths

- Access to 100% of visits to the Hospital Universitario Austral.
- Updated and uniform criteria regarding the hyperbaric oxygen chamber.
- Relevance and impact for the emergency department.

- Access to the follow-up of patients.
- To our knowledge, no publications on the prevalence of acute severe toxicity at neurological level at emergency department are available and there are limited publications at cardiological level.
- Epidemiological data of local population: as far as we know, no data is published regarding the prevalence of carbon monoxide poisoning in the Argentine population.

4.2. Limitations

- Lack of information regarding exposure time to carbon monoxide due to the nature of the pathology presentation (it cannot be quantified for syncope), and there are no data on medical records.
- Data are based on visits to the emergency department of the Hospital Universitario Austral; the statistics do not include other hospitals (single center study).
- Small sample size, with the project of enlarging the database over time.

5. Conclusion

The follow-up of an outpatient population evaluated for carbon monoxide poisoning in the emergency department showed that the prevalence of severe toxicity was significantly lower than that reported in the bibliography so far.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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