The importance of proper territorial planning of hyperbaric centers in the management of carbon monoxide poisoning: case report.

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Keypoints

The article describes the case of a massive influx of patients poisoned by carbon monoxide and the challenges encountered due to the shortage of hyperbaric centers.

Abstract

Carbon monoxide (CO) poisoning remains one of the most common underrecognized conditions. There are no characteristic signs or symptoms of poisoning, and thus, key elements for diagnosis must include careful assessment of the patient's history and circumstantial factors. In January 2019, in the Marche Region, 18 children aged between 12 and 13 and an adult were affected by carbon monoxide poisoning. Due to their clinical conditions, all patients were required to be transferred to hyperbaric centers for appropriate treatment. The significant influx of carbon monoxide-poisoned patients posed a critical challenge in managing these patients due to the shortage of hyperbaric facilities in the region. A widespread and uniform distribution of hyperbaric centers, the adoption of operational protocols, and proper staff training are essential for adequate treatment of the condition.

Keywords

CO poisoning, carbon monoxide, hyperbaric oxygen therapy, CO poisoning management, hyperbaric chamber

Introduction

Carbon monoxide (CO) is a gas produced by the incomplete combustion of organic materials in oxygen-deficient environments. It is slightly lighter than air, colorless, odorless, tasteless, and non-irritating. In Italy, statistics report around 500-600 deaths annually, two-thirds of which are due to voluntary poisoning. These statistics are likely underestimated, as less severe and non-fatal cases are often not properly recorded or diagnosed. Poisoning occurs through inhalation: the inhaled CO binds with hemoglobin, forming carboxyhemoglobin (COHb). This bond is about 200-300 times more stable than the bond between hemoglobin and oxygen, thus preventing normal oxygen transport to peripheral tissues. When one or more CO molecules bind to hemoglobin, the oxygen has fewer available binding sites and is delivered to tissues with greater difficulty. CO also binds to proteins like myoglobin and mitochondrial cytochrome-C oxidase, causing tissue damage. The toxicity of CO is therefore linked to two mechanisms: tissue hypoxia (indirect damage) and tissue inflammation (direct damage). To diagnose CO poisoning, three criteria are required: exposure to a source, clinical signs, and COHb levels. COHb measurement, which represents the amount of hemoglobin bound to CO, is the only test capable of diagnosing carbon monoxide poisoning and should be performed as early as possible. Normal COHb levels are between 0% and 1-2%.

In suspected CO exposure cases, levels higher than 5% (10% in smokers) are considered diagnostic. The main sources of poisoning are water heaters and boilers (39%), fireplaces and stoves (36%). Therefore, the most affected months are winter months (November, December, January, February). CO poisoning remains one of the most frequent underrecognized conditions.

The clinical syndrome of CO poisoning is easily identifiable only when it is severe or presents in multiple patients simultaneously.

There are no characteristic signs or symptoms, and thus, the diagnosis depends heavily on the careful evaluation of the patient's history and circumstantial details. The clinical picture can be highly heterogeneous, with signs and symptoms that are often nonspecific, which can lead to misdiagnosis and/or delay the diagnosis.

In case of poisoning, the severity of the clinical picture is correlated with the concentration of CO in the environment where the patient was exposed and the duration of exposure. (Table 1).

The goal of Hyperbaric Oxygen Therapy is to reduce the half-life of COHb and restor cellular aerobic metabolism. The inclusion criteria for the administration of hyperbaric oxygen therapy are: patients in a coma, patients with temporary loss of consciousness, patients with neuropsychiatric symptoms (in cases of exposure to environments with presumably high concentrations of CO and smoke, the presence of headache associated with one or more neuropsychiatric symptoms is an indication for urgent hyperbaric oxygen therapy, even in patients with COHb levels <25%), patients with uncompensated metabolic acidosis, patients with chest pain, signs of ischemia and/or arrhythmias on electrocardiogram, pregnant patients, and children under 6 months of age due to the presence of fetal hemoglobin (HbF).

SEVERITY CLASS	SIGNS AND SYMPTOMS	
Grade 1: Asymptomatic (*)	Absent	
Grade 2: Mild	Headache Dizziness	Nausea Vomiting
Grade 3: Moderate	Mental confusion Slowed thinking Weakness Ataxia Behavioral abnormalities Alterations in psychometric tests	Dyspnea on exertion Tachypnea Tachycardia Palpitations Hypoacusis Blurred vision
Grade 4: Severe	Stupor Coma Seizures Syncope Disorientation Brain CT scan abnormalities Hypotension/shock Rhabdomyolysis	Chest pain Palpitations Arrhythmias ECG signs of ischemia Pulmonary edema Lactic acidosis Skin blisters Cardiac arrest

Table 1: Signs, Symptoms and Severity of CO Poisoning. (*) Patients with positive COHb levels.

The indication for performing hyperbaric oxygen therapy must also be related to the severity of the clinical condition.

Patients classified as grade 1 should be treated if COHb >25%, except for pregnant patients who should be treated regardless.

Grade 1 patients (with COHb <25%) and grade 2 patients should be evaluated on a case-by-case basis, whereas patients in grade 3 and 4 should always be treated.

While the COHb value is only indicative for the diagnosis of carbon monoxide poisoning and is not, in itself, an index of the severity of the intoxication, it is still recommended, pending further scientific research and on a transitional basis, to treat: asymptomatic patients with COHb >25%, children under 12 years old with COHb >10%, and asymptomatic patients with a history of myocardial ischemia with COHb >15%.

Case Report

In January 2019, eighteen boys aged between 12 and 13 years and one adult suffered carbon monoxide (CO) poisoning.

The source of the intoxication was later identified as a faulty boiler located in the changing room of the sports center where the boys and their coach had stayed after completing their usual football training.

The patients were transferred to the emergency department of the "E. Profili" Hospital in Fabriano (AN).

Upon arrival, 12 patients showed grade 2 poisoning (characterized by nausea, vomiting, diarrhea, abdominal pain), while the remaining 7 patients presented grade 3 poisoning (characterized by nausea, vomiting, drowsiness, spatiotemporal disorientation, and tachypnea).

The simultaneous arrival of multiple patients with these symptoms immediately led the staff to suspect carbon monoxide poisoning.

Oxygen (100%) via a non-rebreather mask was promptly administered, along with blood tests, blood gas analysis, electrocardiogram, and continuous monitoring of vital signs, according to internal protocol. At the same time, the on-call intensive care physician was alerted.

All patients showed carboxyhemoglobin (COHb) levels above 5%, while the ECG showed no signs of ischemia or arrhythmias.

The reference hyperbaric center was contacted and hyperbaric oxygen therapy (HBO) was agreed upon, as none of the patients had contraindications to the procedure. Protected transport was organized to the hyperbaric centers in Fano (PU) and Ravenna, in the Emilia-Romagna region.

Following the HBO treatment cycle, none of the patients developed delayed neurological sequelae during follow-up.

Discussion

Acute carbon monoxide (CO) poisoning is a frequent and underestimated cause of intoxication, with a typical seasonal trend, peaking particularly during the winter months.

The clinical syndrome of CO poisoning is easily recognized only when it is severe and affects more than one person; otherwise, it remains one of the most frequent causes of diagnostic error in emergency departments.

In cases of intoxication, the severity of the clinical presentation is correlated with the concentration of CO in the environment and the duration of exposure.

However, blood COHb levels do not directly correlate with clinical severity or prognosis, making a careful clinical evaluation and thorough medical history essential.

It is well known that high-flow normobaric oxygen therapy using a device with one-way valves should be started immediately upon first aid and continued until the patient is placed in a hyperbaric chamber, if such treatment is deemed appropriate.

Therefore, proper training of emergency and ER personnel, as well as the adoption of internal protocols in each hospital, is essential.

Hyperbaric oxygen therapy aims to reduce the half-life of COHb and restore cellular aerobic metabolism. This treatment should be initiated as early as possible, in the absence of contraindications, to reduce the incidence of delayed neurological sequelae.

In practice, this often conflicts with the logistical and territorial organization of hyperbaric centers.

The distribution of hyperbaric centers across the national territory is highly uneven (as reported in the 2019 SIMSI report), resulting in a lack of homogeneous coverage that may compromise or delay the initiation or administration of hyperbaric treatment when needed. Currently, only one accredited Hyperbaric Medicine center (authorized for emergency care) is operational in the Marche region. Consequently, patients must be transferred to out-of-region centers when necessary.

The existence of a single accredited hyperbaric chamber in the Marche region proved to be a critical issue in managing and treating the patients. Due to the sudden, large, and simultaneous influx of patients, it was necessary to arrange out-of-region transfers, requiring protected patient transport. This inevitably increased the risks and discomfort for patients, as well as the associated costs and organizational efforts. Strengthening the hyperbaric network to achieve a more widespread and targeted distribution of facilities is essential to improve access to care.

In our view, the planning of hyperbaric center locations should also take into account the morphology and characteristics of the territory (ports, road network, etc.), as well as the potential catchment area, to ensure the best response in the shortest time possible.

At present, many Italian hyperbaric centers are located outside hospital structures, which can be a critical issue in the management and transfer of patients, increasing associated risks. The existence of hyperbaric chambers located within hospitals is crucial, allowing treatment of critical patients (such as those in intensive care units) without the need for transport or long journeys to receive treatment.

A key strength in the management of CO poisoning is the possibility of prompt, 24/7 communication between the emergency physician and the hyperbaric specialist.

Conclusion

Prevention, proper training of emergency services, and public awareness represent the first line of defense.

The adoption of simple, clear, and easily accessible guidelines can facilitate communication between emergency departments and hyperbaric centers.

It is desirable for each hospital to adopt an internal protocol to be used in cases of carbon monoxide poisoning.

A widespread and evenly distributed network of hyperbaric centers is essential to ensure proper treatment.

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