Managing a Mass CO Poisoning: Critical Issues and Solutions From the Field to the Hyperbaric Chamber

Adriano Valerio, MD; Matteo Verzè, MD; Francesco Marchiori, MD; Igor Rucci, MD; Lucia De Santis, MD; Irene Aprili, MD; Lucia Antolini, MD; Anna Sannino, MD; Alessia Canello, MD; Enrico Checchin, MD; Francesca Mazzola, MD; Sara Ferrari, MD; Marta Garon, MD; Alberto Schonsberg, MD; Stefano Tardivo, MD

ABSTRACT

Carbon monoxide acute intoxication is a common cause of accidental poisoning in industrialized countries and sometimes it produces a real mass casualty incident. The incident described here occurred in a church in the province of Verona, when a group of people was exposed to carbon monoxide due to a heating system malfunction. Fifty-seven people went to the Emergency Department. The mean carboxyhemoglobin (COHb) level was $10.1 \pm 5.7\%$ (range: 3-25%). The clinicians, after medical examination, decided to move 37 patients to hyperbaric chambers for hyperbaric oxygen (HBO) therapy. This is the first case report that highlights and analyses the logistic difficulties of managing a mass carbon monoxide poisoning in different health care settings, with a high influx of patients in an Emergency Department and a complex liaison between emergency services. This article shows how it is possible to manage a complex situation with good outcome. (*Disaster Med Public Health Preparedness*. 2016;page 1 of 5)

Key Words: emergency medicine, emergency service hospital, environmental exposure, health planning organizations, inhalation exposure

Carbon monoxide (CO) is a colorless, odorless, tasteless, and nonirritating gas resulting from the incomplete combustion of organic substances containing carbon due to oxygen deficiency. Acute CO intoxication is a common cause of accidental poisoning in industrialized countries; in Italy, this intoxication causes more than 6000 hospitalizations and 350 deaths per year.[1] France reports 200 deaths/year and 1000 deaths/year in the United Kingdom.[2,3] In the United States, CO poisonings are responsible for about 50 000 admissions in emergency departments and 5600 accidental or suicidal deaths per year.[4,5]

Furthermore, the nonspecificity of symptoms may lead to an underestimation of the total number of fatal cases. CO poisoning is more common in the winter and occurs most commonly at home, but in a certain percentage of cases, it also happens in the workplace. Common sources of CO are fire, indoor use of charcoal briquettes, furnaces, gasoline-powered electrical generators, and propane-burning appliances.[6] It rarely involves a single subject but more often involves groups of people and sometimes becomes a mass casualty incident.[7] Although CO is the leading agent of lethal inhalations in the United States, with over 10 000 individuals annually losing workdays because of CO toxicity, reports of mass exposures are surprisingly rare.[8] In the medical literature, case reports of mass CO poisoning are most frequently described in situations with indoor combustion and multiple visitors; these include churches, schools, warehouses, and ice arenas.[8] The incident described here occurred in a church in the province of Verona when a group of people breathed carbon monoxide resulting from a faulty heating system. The literature has other examples of mass CO poisoning as well as articles about the hospital burden of CO intoxication[9]; however, this case report is the first to highlight and analyze the logistic difficulties in managing a mass carbon monoxide poisoning in different settings, including the high influx of patients to the Emergency Department and the complex liaison between emergency services. Other important aspects are the adherence to guidelines on the treatment of poisoned patients and management of their simultaneous carriage to the Hyperbaric Therapy Centres.

INCIDENT DESCRIPTION

In January 2015, a children's recital was held in a church in a small town in northeast Italy. The church was serviced by 3 catalytic heaters that were activated in the morning. The recital started at 3:00 pm. At 3:30 pm, some of the 60 people present in the church began to feel sick—first the children and then their parents. The main symptoms were drowsiness, nausea, and temporary loss of consciousness.

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The building was evacuated, and the Fire Department was alerted. Firefighters, suspecting a CO intoxication, recommended people to go to Emergency Department (ED) of the nearest city for a clinical evaluation. After examination of the area, the firefighters found a CO value of 304 mg/m^3 due to 1 catalytic heater with a defective nozzle. The first patient arrived in the ED at 4:45 pm. During the following 2 hours, there was a rush to the ED of the index hospital (a 480-bed regional hospital with a daily turnover of 190 patients on the ED). The high number of patients with the same clinical picture caused the ED doctors to contact the Territorial Emergency Medical Service (EMS) for coordination of transport to hyperbaric chambers (HC) located in 2 other facilities for hyperbaric oxygen (HBO) therapy.

METHODS

Data were collected from the ED and EMS (Emergency Medical Services) reports. The EDs' reports contained all the clinical and laboratory data, as well as the time of arrival, duration, and discharge of patients treated in the ED. The EMS registered all information about time and place of patient transport.

RESULTS

Patients' Treatment in Emergency Department

Fifty-seven people arrived in the ED: 29 females and 28 males. The median age was 14 years (average age 25 ± 20.5 years; range 1-68 years); 37% (21 subjects) were children younger than 12 years old (Table 1). At triage evaluation, 4 people (7%) were classified as white code (not critical condition, not urgent), 44 people (77%) as green code (low critical condition, absence of progressive risk, intervention can be postponed), and 9 people (16%) as yellow code (medium critical condition, presence of progressive risk, possible life-threatening). The mean carboxyhaemoglobin (COHb) level of the 41 patients was 10.1 ± 5.7% (range 3-25%); 36 patients (63.1%) presented COHb levels below 20%, 5 patients (8.8%) had a COHb levels greater ≥20%. The COHb maximum value was 25%. In 16 people (28.0%), it was not possible to recover the initial CO value. All 5 patients with a COHb value higher than 20% were children between 4 and 9 years; 3 were clinically symptomatic at their arrival in ED, and all presented with headache, nausea, and vomiting. Twenty patients (35.1% of total) had at least 1 typical symptom of CO intoxication, including nausea, headache, tachycardia, dizziness, vomiting, drowsiness, and cherry red skin. Twenty-one patients (36%) received oxygen therapy in the Emergency Department, and this was the only therapy administered. After medical examination, the clinicians decided to move 37 patients to hyperbaric chambers for HBO therapy. The ED collaborated with the EMS for transportation of patients to 2 different Hyperbaric Institutes. Twenty subjects did not need HBO therapy, 9 were discharged after the first clinical evaluation, while 11 remained in the ED for a mean time of 249 minutes (range: 145-615). Twenty-seven people were assigned to the first HC (A-HC) and 10 to the second (B-HC), which were 58 and 89 km (travel time 47 and 71 minutes, respectively) from the ED. These patients were transported via 10 ambulances (with only ambulance care assistants on board), activated with code white. The first ambulance was activated at 5:58 pm and the last at 8:14 pm; 2 ambulances aborted the mission because it was not necessary. Each ambulance carried about 3 patients; a firefighter van (named "Bosco 15") was also used, carrying 7 patients. The ambulances moved from their bases located in 6 different places of Verona province from a maximum distance of 58 km. Six vehicles went to A-HC, but only Bosco 15 returned twice to transport patients to the ED: the median time for transport from ED to A-HC was 2 hours. Three vehicles went to B-HC and came back to ED within an average time of 4 hours. As they returned to ED, all patients received a second medical check. Eight patients remained in the ED for observation, and the last patient was discharged at 8:12 am. The second COHb evaluation of all patients before discharge showed values between 0% and 4.2%.

TABLE 1

Main Patient Features[a]

No. of subjects	57
Male	28
Female	39
Age, years (range)	1-68
No. of children (<12 years old)	21
Triage classification	
White	4
Green	44
Yellow	9
Red	—
COHb value, % (range)	3-25
No. of patients with positive clinical	20
No. of patients treated with O_2	21
No. of patients sent to HC	37

[a]Abbreviations: COHb, carboxyhemoglobin; HC, hyperbaric chamber.

DISCUSSION

We identify three topics in the management of this incident that could be useful for the management of future situations.

Activation of Local Emergency Services

Activation of emergency services was critical. Only the Fire Department was alerted after the sudden illness of multiple people present in the church. In this early phase, EMS was not activated—neither by people in the church nor by the Fire Department. Rather, people were requested to reach the nearest ED on their own. EMS was alerted once the medical staff of the ED had to face a high influx of people with similar clinical patterns. This required the transportation of many people for HBO therapy. This is a critical and high-risk situation due to a lack of coordination between territorial emergency services. This decision might influence the capability of the hospital emergency service. It would be better if triage were done by health staff, as is normally done when territorial EMS is alerted. Only medical staff can perform a complete triage and prescribe treatment. If EMS had been alerted before, the ED might not have been overloaded. Another critical point is patient transport to the ED. The lack of coordination could have been avoided by activation of territorial EMS. This lack of coordination caused many people to go the same ED at the same time. Triage by medical staff could have sorted patients based on their clinical conditions to different EDs at different distances. This type of situation needs strong coordination with ED services. The high flux of people to a single ED caused a critical situation for the health care staff, especially in having to perform an initial triage. Hopefully, future situations will use a single emergency telephone number (NUE) a common telephone number for all emergency services (police, fire, medical), useful for their coordination. Actually, the single emergency telephone number is already adopted in some other Italian regions.

In our case report, the EMS helped transport patients to hyperbaric institutes. Several emergency ambulances were warned, even those from a distance of 58 kilometers. They confirmed or denied their availability. The operation center alerted its staff and recruited 2 medical doctors and 3 nurses. It also activated some of their ambulances and made available a medical vehicle that was converted for the transportation of several patients with oxygen storage, more than ambulances carry. This shows the expertise and the versatility of the EMS in the management of critical situations. Skillful coordination of all vehicles allowed the EMS to transport the most people from ED to hyperbaric institutes and return to the ED without threatening the regular service for territorial emergencies.

Emergency Department Response to High Influx of Patients

The medical staff was put through the wringer with the great flow of people arriving at the ED. Three physicians were present before the arrival of intoxicated people, but after activation of the Emergency Management Plan for Mass Casualty Incidents (PEIMAF), 2 medical doctors and 2 nurses were recruited through 8:30 pm. They came from the Paediatric Unit in light of the large number of children involved. Through 8:00 pm, 2 medical doctors out of 3 tended to intoxicated people, while the other physician continued to manage the other cases. The night shift arrived at 8:00 pm, and 2 doctors from the previous shift remained in the ED through 10:00 pm and 8:00 am the next day, respectively. The ED nursing staff recruited 2 nurses called from availability, and they were involved in the management of the patients returned from Hyperbaric Institutes. Two medical doctors from Medical Administration went to the ED and supported the medical staff for the emergency. Due to the extra staff, the high patient volume did not cause clinical problems. This was obtained due to successful activation and functioning of the PEIMAF. Here, we highlight the high impact of an organized PEIMAF that can be efficaciously activated in a medium-sized hospital. There are not many documented examples of these situations in Italy. This case offers an opportunity to study the successes and challenges in dealing with these large-scale situations. Of note, the incident happened on a holiday when health care staff was reduced both in the hospital and in the territory; nevertheless, the situation was managed without negative incident.

Finally, an aspect that cannot be omitted is the lack of the completeness of clinical documentation of patients throughout the care. In mass treatment events, documentation is the first component dismissed, clearly because sudden increase in workload due to the complex situation; the priority is to take care of patients' health rather than the correct management of clinical documentation. It does limit our ability to analyze data on these events but, even so, there is a choice between patient care and documentation, and the correct decision is for patient care. Nevertheless, the completeness of the data cannot be underestimated. Accurate reporting is critical to improve care and for legal reasons.

Clinical Management of Intoxicated People

We also analyzed the adherence to guidelines on HBO therapy in the management of intoxicated people in the ED. We searched for published national and international guidelines on the utilization of HBO therapy for patients with carbon monoxide poisoning. We identified 3 published guidelines: 1 by the Centers for Disease Control and Prevention (CDC; Table 2),[10] 1 published by the Italian Society of Emergency-Urgency Medicine (SIMEU; Table 3),[11] and 1 developed through collaboration between the Italian Society of Anaesthesia, Analgesia, Intensive Care (SIAARTI), the Italian Society of Diving and Hyperbaric Medicine (SIMSI), and the National Association of Private Hyperbaric Chambers (ANCIP; Table 4).[12] As reported in all 3 tables, the clinical condition of the patient is the most important factor when considering utilization of HBO. The COHb value is essential to diagnose CO intoxication; however, its level is

TABLE 2

Conditions That Prompt Consideration of Hyperbaric Oxygen Therapy (HBO) in CO Poisoning[a]

COHb Level	Clinical Evidence
>25-30%	cardiac involvement, severe acidosis, transient or prolonged unconsciousness, neurological impairment, abnormal neuropsychiatric testing, or the patient is ≥36 years in age
<25%	Clinical condition and history of exposure
Diagnostic for CO poisoning	Pregnant women

[a]Source: Centers for Disease Control (CDC), "Clinical Guidance for Carbon Monoxide (CO) Poisoning After a Disaster." Last update: June 2014.

TABLE 3

Recommendations Regarding the Utilization of Hyperbaric Oxygen Therapy (HBO)[a]

Recommendation	Grade of Recommendation
Hyperbaric oxygen therapy is indicated in patients with a medium (grade 3[d]) or severe (grade 4[e]) level of intoxication. Patients treated with hyperbaric oxygen Therapy have to receive normobaric therapy before and after hyperbaric sessions(s).	Grade B
Patients with a medium (grade 3) or severe (grade 4) level of intoxication should undergo hyperbaric oxygen therapy until 6 hours from the finding.	Grade B
Pregnant women should undergo hyperbaric oxygen therapy whatever level of intoxication they present (Grade 1[b] – 2[c] – 3 – 4)	Grade C

[a]Source: Italian Society of Emergency-Urgency Medicine (SIMEU), April 2001.
[b]Grade 1: asymptomatic.
[c]Grade 2: headache, dizziness, nausea, vomiting.
[d]Grade 3: confusion, slowness of ideation, blurred vision, weakness, ataxia, behavioural abnormalities, shortness of breath, exertional dyspnoea, tachycardia, tachypnea, alterations in psychometric tests.
[e]Grade 4: drowsiness, dulling of sensorium, coma, seizures, faint, disorientation, abnormalities on brain CT, hypotension, chest pain, palpitations, arrhythmia, ECG patterns of ischemia, pulmonary oedema, lactic acidosis, myonecrosis, skin blisters.

TABLE 4

Inclusion Criteria for Treatment With Hyperbaric Oxygen Therapy (HBO)[a]

Clinical Findings	COHb Levels
Coma	Diagnostic for CO intoxication
Temporary loss of consciousness	Diagnostic for CO intoxication
Neuropsychiatric symptoms	Diagnostic for CO intoxication
Metabolic acidosis	Diagnostic for CO intoxication
Chest pain and ECG patterns of ischemia	Diagnostic for CO intoxication
Arrhythmia	Diagnostic for CO intoxication
Pregnancy	Diagnostic for CO intoxication
Children <6 months (presence of HbF)	Diagnostic for CO intoxication
Asymptomatic	COHb > 25%
Asymptomatic children <12 years	COHb > 10%
Asymptomatic, with previous myocardial ischemia	COHb >15%

[a]Source: Italian Society of Anaesthesia, Analgesia, Intensive Care (SIAARTI), Italian Society of Diving and Hyperbaric Medicine (SIMSI). and National Association of Private Hyperbaric Chambers (ANCIP), March 2007. Abbreviations: CO, carbon monoxide; COHb, carboxyhemoglobin; ECG, electrocardiogram.

not necessary directly proportional with the severity of the poisoning. Nonetheless, the threshold value of COHb that generally induces HBO therapy is 25%. Only more recent criteria (Table 3) have focused on children. The data confirm that children are more susceptible to CO poisoning because they have higher basal metabolic rates and tissue oxygen demands.[13] The threshold level of COHb that leads to HBO therapy is lower in children (10%) than in adults. Patients with previous myocardial ischemia are also at higher risk (threshold level of COHb 15%).

In this case report, after clinical examination and laboratory tests, the clinicians of the ED decided which patients had to be treated with HBO therapy. Of the 37 patients sent to HBO therapy, 6 had no usable data. According to guidelines, 13 out of 31 patients were correctly sent from the ED to Hyperbaric Institutes; the other 18 patients did not need HBO therapy. Twenty patients remained at the ED. This was correct for 18, but 2 had no usable data. Overall, 31 patients (63.3%) were correctly managed by the ED, and 18 (36.7%) patients received "excessive care," according to guidelines. It is important to consider that this lack of adherence to guidelines by the ED was not a deficiency of treatment. For 8 patients, there were no clinical or laboratory data. The decision by ED to send patients to HBO therapy without the need for it risked collateral effects in healthy people and was an unnecessary use of resources. Further, HBO can cause middle ear or pulmonary barotraumas as well as pain and claustrophobia.[14-16]

No one of the 3 guidelines analyzes the time period between CO poisoning and HBO therapy and its relation with outcomes. In literature, there are not clear indications about the therapeutic window of time. Coric et al[17] suggested that when hyperbaric oxygen is used, immediate treatment is preferred for best results. Moreover, recent in vitro studies on cultured astrocytes have demonstrated that the protective and beneficial effect of HBO therapy is time-dependent and suggested the importance of the time period between CO exposure and HBO therapy, this has to be investigated in vivo with further studies.[18] However, the efficacy of hyperbaric versus normobaric oxygen therapy in CO intoxication remains controversial even if several studies suggest its potential benefit in reducing the incidence of delayed neuropsychiatric sequelae.[18,19]

This case report demonstrates that in emergency situations, the ED has difficulties in appropriately managing all cases. This can cause it to request a specialist consult for the high number of patients. This behavior is likely because of high patient load over a short period. Sending patients to a safer facility might reduce the caseload and legal burden. These difficulties might also originate from a lacking preparation for these kinds of events. Furthermore, other studies indicate that the knowledge and behavior of primary care medical staff in terms of mass emergencies are not satisfactory. The response capacity of medical staff is still relatively low.[20] However, this minimum level of knowledge is not broadly disseminated. Jefferson concluded that "available evidence is insufficient to determine whether a given training intervention in disaster preparedness for health care providers is effective in improving knowledge and skills in disaster response."[21] Firstly, the studies about field triage and training intervention are very different and flaw in methodology.[21] Secondly, there are many typologies of training systems with different kinds of results: By way of example, 1 of them showed how bioterrorism computer-based training did not improve the physicians' knowledge.[22] Another work explains how the communication skills and coordination in acute care teams can be improved by simulation.[23] However, Nilsson et al demonstrated how firemen triage training improve triage accuracy in mass casualties, and this is very interesting because they usually arrive at the patient before medical staff.[24] In the future, the adoption of universally and standardized evaluation criteria will improve the comparison of results and the strength of evidence about the most effective methods of training for disaster response.[21]

CONCLUSIONS

Acute monoxide intoxication can cause of massive influx of patients to the ED. This article analyzed how to manage a sudden and massive flux of CO-poisoned patients with a good outcome. This also underlines some complexities that occur in every health system: First, proper management of these situations might start from the field and cannot be delayed. Second, coordination between different health institutions is essential but very difficult because of the unpredictability of these events. Third, the formulation of emergency plans, protocols, and guidelines can be useful even if there is often insufficient knowledge or training. These key factors should be constantly improved to provide more efficient care and improve the outcome of patients and success of the health system.

About the Authors

Department of Emergency and Intensive Care Unit, Operation Center SUEM, Azienda Ospedaliera Universitaria Integrata (AOUI), Verona, Italy (Drs Valerio and Schonsberg); Diagnostics and Public Health Department, University of Verona, Verona, Italy (Drs Verzè, Marchiori, Rucci, Aprili, Antolini, Sannino, Canello, Checchin, Mazzola, Ferrari, Garon, and Tardivo); and Emergency Department, Mater Salutis Hospital, Legnago (Verona), Italy (Dr De Santis).

Correspondence and reprint requests to Dr Francesco Marchiori, Diagnostics and Public Health Department, University of Verona (AOUI), Istituti Biologici II - Blocco B, Strada le Grazie 8, 37134 Verona, Italy (e-mail: framarchiori@gmail.com).

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