Carbon monoxide intoxication - diagnosis and treat

June 1999

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The effects of carbon monoxide poisoning have been found to be greatly alleviated, or in some cases eliminated, through the use of hyperbaric oxygen therapy. This paper discusses the pathophysiology of carbon monoxide intoxication and presents an overview of its treatment.

Introduction

Intoxication by carbon monoxide (CO) is a very serious, potentially lethal, frequent, often overlooked, and often insufficiently treated medical emergency. A French study showed that about 30 % of CO poisonings were inadequately evaluated at first contact with the health system [1].

CO is dangerous as it is an odorless, colorless gas with a high diffusion rate. It has a molecular configuration similar to that of oxygen and nitrous oxide, and due to its higher affinity to various sites, the intoxication picture has many aspects.

Sources of co intoxication

CO is liberated into the environment as one of the waste products from the incomplete combustion of carbon-containing materials. The toxic effect is enhanced if CO is liberated in a closed room or other confined space.

The sources are numerous - exhaust gases from engines, defects in funnels from furnaces and ovens, and from the use of kerosene heaters and stoves in poorly ventilated rooms. A number of patients are rescued from fires, intoxicated by the smoke and fumes from the fire, and often with concomitant burns.

Clinical presentation

The suspicion of CO intoxication may be based on the patient's history and the history of the accident. The clinical symptoms of intoxication may be numerous, increasing with the increased absorption of CO. The first neurological signs are a severe headache, irritability, lack of short-term memory, agitation, and combativeness.

In later stages, confusion, lethargy, spasticity and unconsciousness, are observed. The cardiac function is marked by mild hypotension, but with increased intoxication, increased pump failure will occur, as well as arrhythmia in the form of sinus tachycardia, atrial flutter and fibrillation, T waves inversion changes, premature ventricular contractions, and ventricular tachycardia and fibrillation.

The prehospital deaths may be due to marked hypotension and arrhythmia [2]. In some cases, the history of rescue from fires or defective heating devices etc. will give a direct lead to the diagnosis.

However in other cases, the symptoms of poisoning from low concentrations of CO may mimic a series of other diseases such as influenza, tension headaches, myocardial infarction, etc.

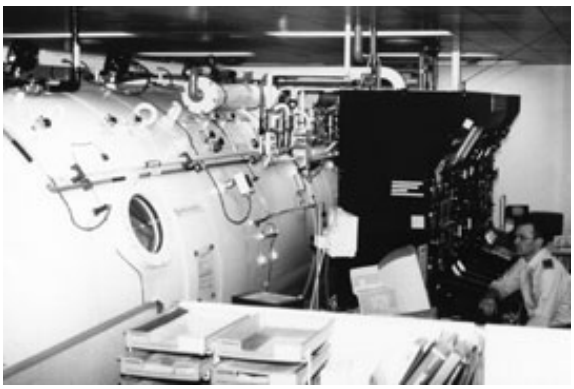

Fig. 1: The hyperbaric oxygen chamber at Rigshospitalet, Denmark, seen from the outside.

Diagnosis

A blood gas sample is essential for determining CO intoxication, and the parameter of interest is carboxyhemoglobin. Carboxyhemoglobin is a measure of the carbon monoxide concentration in the red blood cells, but not the cellular levels of carbon monoxide in critical areas such as the brain and myocardium.

It is essential to measure CO using a spectrographic method. One should not try to extrapolate the measured pO_2(aB) level as evidence of a nonsaturated equilibrating *F*COHb level.

Under normal conditions a value of about 0.85 % *F*COHb is found, as CO is a degradation product of hemoglobin. In smokers, the value may rise to about 4 %, and in heavy smokers it may reach up to 9 %. It does not matter whether the sample is taken from a vein or artery.

Pulse oximetry does not provide any information since the method can not distinguish between oxyhemoglobin (O_2Hb) and COHb. The clinical picture is the guideline for further treatment.

Many handbooks describe a correlation between increased signs of intoxication with increasing COHb. However these tables are based on experimental research and have little reference to the clinical situation [2].

PATHOPHYSIOLOGY

Binding to hemoglobin

CO crosses the alveolocapillary membrane easily and binds to hemoglobin with an affinity which is about 250 times higher than that for oxygen, blocking the oxygen binding capability [3].

Furthermore, COHb has a structure which gives a left shift of the oxygen dissociation curve. A concomitant reduction of 2,3-diphosphoglycerate increases the left shift of the oxygen dissociation curve, adding to the problem.

Thus CO induces hypoxia. The amount of CO that is absorbed depends on the concentration of CO in the environment, the alveolar ventilation, the duration of the exposure [4], and the cardiac output.

Effect on circulation

The lung capillary blood flow rises considerably within minutes following exposure to CO. It is assumed that the effect is similar to that caused by nitric oxide (NO), the so-called endothelium-derived relaxation factor [5].

Effect on the heart and muscles

Myoglobin is the oxygen carrier in cardiac and skeletal muscle. The binding of CO to myoglobin leads to a nonfunctional form of myoglobin. It has been found that the affinity of CO to myoglobin is similar to its affinity to hemoglobin - about 250 times greater than that for oxygen to hemoglobin [6].

This reduced oxygen delivery to muscle cells is the explanation for limitations in the maximal oxygen consumption, and for the decrease in cardiac output that is found in patients with CO poisoning.

Pregnant patients face an increased risk of threatening the fetus, as fetal hemoglobin has a 15 % greater affinity to CO compared to the affinity of oxygen to adult hemoglobin [7]. This means that CO will be transported from the mother to the fetus, reducing the oxygen carrying capabilities.

Effect on metabolism

Cytochrome A3 has a central role in electron transport in mitochondria, catalyzing the reduction of molecular oxygen to water. This function accounts for 90 % of the total oxygen uptake of the body.

CO is able to bind to cytochrome A3, thereby blocking the consumption of oxygen and the generation of ATP [8]. There seems to be evidence that in the brain cytochrome A3 is blocked by CO, producing a histotoxic hypoxia. This effect is reinforced by the concomitant hypoxemic hypoxia.

First aid

The patient should be removed from the CO atmosphere as soon as possible, and immediately given oxygen via a mask. If the patient is unconscious or has unstable respiration, the patient should be intubated. The treatment, therefore, is initially the same as at any scene of emergency.

In cases of suspected CO intoxication, the patient should have oxygen until a definitive diagnosis has been established at the hospital. The importance of oxygen treatment is supported by the observation that the dissociation rate of COHb is exponential.

The half-life of COHb for a patient breathing atmospheric air is 230 - 320 min. When pure oxygen is breathed, the half-life is reduced to 90 min [9].

Hospital treatment

When the patient is received in hospital, a further course of treatment is planned. Besides symptomatic treatment of respiration and circulation, a blood sample should be analyzed for COHb and biochemical signs of muscle necrosis.

An EEG should also be taken, as patients with coronary artery disease are especially at risk of myocardial infarction after being exposed to CO [10]. A thorough neurological examination should be carried out.

From our experience, the Rombergs test, finger-nose test, and knee-heel test are sensitive indicators in cases of light intoxication. However reduced asymmetric muscle force and patchy anesthetic areas on the skin are often found.

With heavier intoxication the symptoms are as mentioned above. The main aims of treatment are primarily to provide survival of the patient, and se-condarily to reduce or avoid late neurological sequelae.

Theory of hyperbaric oxygen treatment

With respect to meeting these aims, HyperBaric Oxygen (HBO) treatment is shown to beneficial [11]. The pressure in the hyperbaric chamber is 2.5 - 3.0 ATA and the patient breathes pure oxygen.

At these pressures the oxygen tension is 17 - 21 times higher than in air at normal atmos-pheric pressure. As the half-life of COHb is reduced to 22 min. in a pressure chamber at an ambient oxygen pressure of 3 ATA, the CO in hemoglobin and myoglobin is rapidly cleared [9].

The function of cytochrome A3 seems to be rapidly normalized under hyperbaric conditions, while normobar oxygen pressure gives rise to a slow CO-cytochrome A3 dissociation and the possible generation of oxygen free radicals and tissue injury [12].

In another study it was shown that under HBO treatment there was a dramatic decrease in leucocyte adhesion to endothelial cells, compared to reoxygenation at normal oxygen pressure.

Outcome of hbo treatment

The outcome without the use of HBO treatment appears to be quite serious. A study from 1973 [13] showed a 10 % immediate gross neurological sequelae. 33 % of patients were subsequently found to have personality deterioration, and 43 % had memory disturbances.

However the majority of treatments were insufficient or delayed. The prognosis seems better if HBO treatment is applied. In a study by Mathieu [14] in which patients were treated with HBO, only 4.4 % of them suffered from persistent manifestation with only 1.6 % having major impairments after one year.

International consensus of treatment

A committee under Undersea and the Hyperbaric Medical Society [11] has concluded that the cost of HBO treatment in these conditions is modest, since it is a primary mode of therapy.

Additionally, prevention of morbidity from delayed neurological sequelae represents a substantial cost savings to the health care system and society.

Hbo treatment in denmark

According to Danish regulations [15] a CO exposed patient should be considered for HBO treatment if the patient has at least one of the characteristics:

- any neurological abnormal findings (more than a usual headache)
- signs of cardiac dysfunction
- is or has been unconscious
- is pregnant
- has a *F*COHb of 25 % after 2 hours of normal atmospheric pressure oxygen administration.

The patient is then transferred to a hospital with a hyperbaric chamber as quickly as possible. Oxygen is given during the transport.

The hospital system in Denmark offers a 24 hours a day hyperbaric service at two hospitals. At one institution there is a chamber that takes one patient at a time. Our institution has recently established a larger chamber offering space for 8 seated patients or 2 beds.

The chamber is equipped for full intensive treatment, including respirator and monitors for invasive pressures, ECG, temperature regulation, and facilities to analyze the respired gas.

On arrival at the hospital general and neurological examinations are performed. As preparation for hyperbaric treatment, the patient is tested on their ability to autoinflate the middle ear. If this is not possible or if the patient is unconscious, a tympanotomy is carried out.

Shortly after this the patient is taken into the hyperbaric chamber, a mask with pure oxygen is mounted onto the patient's face, and the chamber is set to a pressure of 2.8 ATA, equivalent to the pressure under 18 meters of sea water. Usually a specially trained anesthesiologist takes care of the patient in the chamber.

Conscious patients can benefit from having company in the chamber, but combative and obtundent patients may need sedation, or a proprofol anesthetic may have to be administered. Patients with unstable respiration are intubated and ventilated. It is essential to be prepared to take care of pulmonary edema, as this may occur due to left heart failure, or aspiration of toxic smoke from fires at the scene of the accident.

Each treatment lasts 90 minutes, and repetitive

treatments are given if the patient is not fully recovered. In a multiplace chamber it is possible to monitor the blood gases, since samples can be taken from the patients via a medicine lock using a syringe, and sent to the laboratory for analysis. However one has to take care that there are no bubbles in the syringe, as this will give rise to considerable error during decompression of the syringe.

The treatment is repeated if the patient has not fully recovered neurologically, and the series of treatments is continued until no further progress is seen. In our institution, typically 3 treatments are given to CO intoxicated patients.

On discharge from the hospital, patients are given written information about the risk of renewed neurological deterioration, and asked to contact the unit immediately for reassessment with the possibility of additional HBO treatment.

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