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Carbon Monoxide Poisoning

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Abstract

Carbon monoxide (CO) poisoning is the most common cause of mortality due to inhalation toxicity. CO can affect multiple systems in the body and manifest a wide range of symptoms; thus, the diagnosis of CO poisoning can easily be overlooked. In reality, the cases of CO poisoning is much higher than reported, which makes it crucial to take first-step protective measures. The most sensitive tissues to CO poisoning are vital organs (brain, heart) with a high oxygen demand. Neuropsychiatric syndrome which may develop in the chronic period (three to 240 days) should also be considered. If diagnosed, the treatment of CO poisoning should be symptomatic and aimed at removing carboxyhemoglobin (COHb) from the blood, coupled with provision of effective basic life and advanced cardiac life support. The best way to remove COHb is to deliver 100% oxygen. Hyperbaric oxygen (HBO) therapy reduces COHb much faster; therefore, patients with the indications of HBO therapy should be started on this treatment without delay.

Keywords: carbon monoxide, poisoning, hyperbaric oxygen, carboxyhemoglobin

Özet

Karbonmonoksit (CO) zehirlenmesi; İnhalasyon zehirlenmelerine bağlı ölümlerin en sık sebebidir. CO, Birçok sistemi etkileyerek çok çeşitli semptomlar gösterebilir ve CO zehirlenmesi tanısı atlanabilir. Toplumda karbonmonoksit zehirlenmesi olguları, kayıtlarda bildirildiğinden daha fazladır. CO zehirlenmesi ile mücadele etmede ilk adım koruyucu tedbirler olmalıdır. CO zehirlenmesine en duyarlı dokular oksijen ihtiyacı yüksek olan hayati organlardır (beyin, kalp). Akut dönemde görülebilen nörolojik, kardiyak durumlar haricinde kronik dönemde (3-240 gün) gelişebilecek nöropsikayatrik sendrom unutulmamalıdır. Teşhis edilmesi halinde tedavi semptomatik ve kandan karboksihemoglobini (COHb) uzaklaştırmaya yönelik olmalıdır. Aynı zamanda etkili bir temel yaşam desteği ve ileri kardiyak yaşam desteği sunulmalıdır. COHb'yi uzaklaştırmanın en iyi yolu %100 oksijen verilmesidir. Hiperbarik oksijen (HBO) tedavisi COHb'yi çok daha hızlı düşürür. HBO tedavi endikasyonu olan hastalara HBO tedavisi gecikmeden başlanmalıdır.

Anahtar kelimeler: karbon monoksit, zehirlenme, hiperbarik oksijen, karboksihemoglobin

Introduction

By definition, poisoning is the destruction or injury of cells by inhalation, ingestion, injection or absorption of a toxic substance. Carbon monoxide (CO) is an odorless, tasteless, colorless, non-irritating gas produced by the combustion of fuels. CO exposure differs according to societies, climatic conditions, and development levels of countries. In countries with cold climate conditions, especially during the winter months, CO poisoning is associated with the use of heating equipment (e.g., stove, water heater, and boiler), while in developed countries, it is mostly reported to be caused by household and industrial accidents, exhaust gases, and suicide attempts. Some professional groups, such as firefighters, police, and industrial workers are also at higher risk of poisoning[1-4].

More than 50,000 people are admitted to the emergency department every year in the US due to CO poisoning[5]. However, in Turkey, there are insufficient studies on the incidence of CO poisoning. In one study conducted in 2010, the number of referrals to the emergency department due to CO poisoning was reported as 10,154[6]. It is clear that due to insufficient records and the insidious nature of CO poisoning, its actual incidence is much higher. Toxicity-associated death is most commonly caused by CO poisoning, and the research into the mortality rates of this emergency reveals that it varies according to country and climate conditions[7-10]. Since CO is odorless and colorless, it is difficult to diagnose; thus, the actual mortality rate is higher than registered[11,12].

Pathophysiology of CO poisoning

CO affects the tissues in different ways:

- CO binds to hemoglobin (Hb) with an affinity of 200-300 times higher than oxygen and forms the carboxyhemoglobin (COHb) molecule. COHb causes hypoxia and asphyxia in the tissue by preventing the transport of oxygen in the blood and its release into the tissues.

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- CO destroys mitochondrial function by binding to cytochrome-c oxidase, and thus causing oxidative phosphorylation and leading to lactate formation and acidosis.
- CO also binds to myoglobin with 20-50 times higher affinity than oxygen, causing myocardial damage through tissue hypoxia and leading to rhabdomyolysis.
- COHb causes leukocyte-dependent inflammatory changes and lipid peroxidation in the brain. In addition, it results in demyelination edema in the white matter and reperfusion injury[13-15].

Diagnosis and clinical features

The first and most important step in the diagnosis of this emergency is to suspect that the patient may have CO poisoning and obtain a targeted history. The diagnosis of CO poisoning is based on a high COHb level measured by an arterial or blood gas sample together with a compatible history and physical examination findings[13]. The normal blood COHb level is below 3%, but it can reach 10-15% in smokers. Symptoms often start at a COHb of 10% and 30%, and death can be seen at 30% or higher. However, the COHb level alone is not reliable in determining the clinical features of the patients[16,17]. Not only the blood concentration of COHb, but also the exposure time determines the severity of poisoning. It has been shown that exposure to CO at a low dose but over a long time may lead to more severe and longer-term toxicity than acute high-dose exposure[18,19].

The best way to determine COHb is to measure it in arterial or venous blood gas. A non-invasive CO-oximeter can also be used for this purpose; however, there are different opinions concerning the measurement of the COHb level with this method due to its sensitivity being lower compared to invasive blood gas analysis. However, CO-oximeter measurement is often undertaken as the first step due to its non-invasive nature, reproducibility, and low cost; nevertheless, it should not be used alone for diagnosis[15,20].

Other methods employed in the diagnosis of CO poisoning include blood gas analysis, biochemistry tests (blood urea nitrogen, creatinine, etc.), cardiac biomarkers showing myocardial damage (troponin, myoglobin, etc.), urinalysis (myoglobinuria, hematuria, proteinuria, etc.), electrocardiography (ECG), computed tomography (e.g., brain edema), and magnetic resonance imaging (MRI) (demyelinating damage, brain edema, etc.)[12,21].

Clinical Presentation

The tissues with high metabolic needs (brain, heart) are at high risk. Classical symptoms include non-specific complaints, such as headache, dizziness, nausea, vomiting, dyspnea, and/or chest pain. Headache is the most common complaint at 91%[22,23]. None of the symptoms are pathognomonic. Redness can also be seen in the cheeks; however, this alone has no sensitivity for diagnosis. Neurological sequelae, acute renal failure, myocardial damage, syncope, and rhabdomyolysis are associated with the severity of CO poisoning[23-26]. In addition, the mortality rate of patients followed up after exposure to CO poisoning has been found to be three times higher than the normal population. Another important clinical condition is delayed neuropsychiatric syndrome, which is characterized by cognitive changes, personality changes and movement disorders that may develop in the later period (within three to 240 days). This syndrome, usually occurring within 20 days of poisoning, may be temporary or permanent[27-30].

Patients can be safely discharged after treatment, even in the presence of simple symptoms, such as headache, nausea, and vomiting. However, if symptoms suggestive of brain and myocardial damage; e.g., syncope, loss of consciousness, or chest pain are observed, hospitalization is required for a longer follow-up and treatment[14].

Management

The main aim of treatment is to provide oxygen for the vital organs as soon as possible and remove COHb from the blood. Effective basic life support and advanced cardiac life support are also crucial. Furthermore, the treatment of CO poisoning is based on a symptomatic battle against the inflicted injuries (such as seizure and cardiac arrhythmia) and the conditions that may develop in the future (e.g., myoglobinuria, rhabdomyolysis, compartment syndrome, and neuropsychiatric syndrome). If necessary, the physical activities of the patients should be restricted for one to three weeks, body oxygen requirement should be reduced, and the patients should be called for a follow-up after discharge, bearing in mind that neurological and cardiac damage can later develop[13,31,32].

In CO poisoning, antidote treatment aims to remove COHb from the blood by providing oxygen. Under normal atmospheric pressure, the life of COHb is four to six hours in ambient air, decreasing to 40-80 minutes through the provision of 100% normobaric oxygen. Using hyperbaric oxygen (HBO) therapy, the half-life of COHb is reduced to 15 to 30 minutes[33,34].

Hyperbaric oxygen (HBO)

This is used as primary or adjunctive therapy for various medical conditions. In this therapy, the patient breathes 100% oxygen intermittently at 1 to 3 ATA in a pressure chamber with single or multiple occupancy. HBO therapy is most commonly used to treat decompression sickness and gas embolism in

cases of CO poisoning and tissue hypoxia. Other uses of this therapy include anaerobic infections (gas gangrene, diabetic foot), compartment syndrome, acute traumatic ischemia (crash injury), refractory osteomyelitis, radiation-related bone and soft tissue necrosis, and thermal burns[35-39].

HBO increases the production of free oxygen radicals (superoxide, hydroxyl radical, peroxides, aldehyde hypochlorite, and hypochlorite) and shows bactericidal activity against anaerobic bacteria without defense systems to these radicals. HBO therapy shortens the half-life of COHb that occurs in CO poisoning. Breathing 100% oxygen under normal atmospheric pressure increases the amount of dissolved oxygen in the blood up to five times. At higher pressures, HBO can increase the amount of dissolved oxygen in the plasma up to 20 times, which is sufficient for the supply of oxygen to the cells, regardless of hemoglobin at rest[40,41].

HBO indications in CO poisoning are;

- Coma,
- Loss of consciousness in any period after CO poisoning,
- COHb level being >30-40% (>15% for pregnant patients and those with a history of cardiac disease,
- Severe metabolic acidosis,
- ECG changes suggestive of myocardial damage and increased cardiac enzymes,
- Symptoms not regressing within four to six hours of normobaric 100% oxygen application[13,20].

Untreated pneumothorax is an absolute contraindication to HBO therapy. Relative contraindications include obstructive pulmonary disease, asymptomatic pulmonary bleb, or bullous lung on chest X-ray, upper respiratory or sinus infections, recent ear or thoracic surgery, uncontrolled fever, and claustrophobia (8,40). In studies with a limited range, adverse events that may occur as a result of HBO therapy have been reported as hypertension, seizure, ear and sinus barotrauma, claustrophobia, oxygen toxicity, dizziness, and pneumothorax[42].

Follow-up and discharge

Clinical improvement in patients presenting with CO poisoning is more significant than the COHb level. Patients that have an indication of HBO therapy should be referred to an HBO center. Normobaric 100% oxygen should be started immediately in patients with no organ damage and 10-30% of COHb levels, and they should be monitored for at least four to six hours. The patients can be discharged when their COHb level falls below 10% and complaints (headache, nausea, dizziness) begin to disappear. However, HBO therapy should be initiated (or the patients should be referred to an HBO center) if the clinical status does not improve within four to six hours of normobaric 100% oxygen treatment. It should also be kept in mind that there may be neurologic and cardiac damage in the late period[19,43].

Discussion

The prediction and prevention of exposure to CO are less costly and more effective in the battle against CO poisoning. CO poisoning occurs more frequently especially in the winter months due to the burning of CO sources for heating purposes. Daily weather conditions and waft can also affect exposure[4,6,44]. In this regard, citizens should be informed about meteorological conditions and the correct use of fuels. In the literature, it was also reported that CO exposure was higher in certain occupational groups[45]. Therefore, in these occupational groups, the use of protective equipment, detectors that can measure the CO level, and appropriate ventilation systems should be made obligatory.

CO is insidious and its diagnosis can be overlooked unless the doctor suspects a poisoning case. An appropriate diagnosis is possible through a combination of appropriate clinical manifestation and high blood COHb levels. The best method for determining the COHb level is to measure it in arterial or venous blood gas. Despite the conflicting opinions about the use of a non-invasive CO-oximeter on the fingertip, it still presents as a feasible method due to its non-invasive nature, reproducibility, ease of clinical use, and low cost[13,20,21]. However, further studies are needed concerning this issue.

Patients presenting with acute renal failure or myocardial and neurological damage have high rates of mortality and morbidity[21,29]. These patients should be hospitalized immediately and the HBO therapy should be started. After a long-term monitoring, these patients can be safely discharged if their COHb is reduced to the normal level; however, it is crucial to follow up these patients after discharge.

Although HBO therapy is the most widely accepted method of treatment in CO poisoning, there are publications suggesting that it does not reduce long-term neurological sequelae and mortality[46]. Furthermore, the longer time between CO exposure and HBO therapy, and loss of consciousness or coma at the time of hospital admission have been found to significantly increase the incidence of delayed neuropsychiatric syndrome[47]. Despite the lack of a conclusive consensus on the indications for HBO therapy, it should be started without any delay in appropriate cases[4,22]. In addition, normobaric 100% oxygen should be administered until HBO therapy is started considering that both treatments accelerate the removal of CO from the blood[23,48].

In a study conducted with 12 patients presenting with severe CO poisoning, a low Glasgow coma score, and a high COHb level (38-79%), the authors applied therapeutic red cell-exchange therapy and discharged 11 patients after rapid

clinical improvement[49]. In another study, 17 patients treated with the same method for CO poisoning were all discharged with full recovery[50]. In both studies, it was emphasized that therapeutic red cell-exchange therapy may be an effective treatment for reducing morbidity and mortality in CO poisoning. However, both studies were undertaken with a small number of patients; thus, further studies with larger case series are needed.

Conclusion

CO poisoning is the most common cause of death due to toxicity. It should be kept in mind that CO can affect all body systems, and primarily the vital organs. In addition to coma and cardiac damage observed in the acute period, other events, such as delayed neuropsychiatric syndrome can also develop. Exposure to CO is higher in winter and in certain occupational areas, which require protective measures to be taken. To date, HBO therapy has been reported to be the most widely accepted treatment in the literature. Therefore, in patients with relevant indications, HBO therapy should be started immediately.

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