Available online at www.medicinescience.org

ORIGINAL ARTICLE

Medicine Science International Medical Journal

Medicine Science 2021;10(4):1179-82

Analysis of patients administered hyperbaric oxygen therapy with diagnosis of carbon monoxide intoxication

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Received 28 April 2021; Accepted 13 July 2021
Available online 01.12.2021 with doi: 10.5455/medscience.2021.04.144

Abstract

Carbon Monoxide (CO) poisoning results in an estimated 10,000 emergency department visits in Turkey annually. CO poisoning cases occurs mostly in Marmara Region including the province of Bursa. CO poisoning is common in where the climate is colder and especially when the use of stoves. In our clinic between September 2016 and August 2017, 127 patients treated with hyperbaric oxygen (HBO) for CO poisoning were evaluated retrospectively for the effects on outcomes. The mean age of the patients was 35.9 years. CO poisoning cases were more prevalent in winter. The mean elapsed time between admission to emergency department and HBO therapy clinic was found 3 hours. Patients were safely treated at 2.4 ATA for 120 minutes. Most of the patients were discharged with recovery. One (0,8%) patient died due to carbon monoxide poisoning. Wide Spreading the HBO therapy centers that may service in emergencies can provide faster access of patients to HBO therapy when needed. This analysis contributed the body of knowledge about CO poisoning in Turkey

Keywords: Hyperbaric oxygen therapy, carboxyhemoglobin, carbon monoxide poisoning

Introduction

Carbon monoxide (CO) is a colorless, odorless, tasteless, non-irritant gas. Acute CO poisoning is potentially fatal. CO poisoning is common in where the climate is colder and especially when the use of stoves and water heaters with inadequate ventilation. CO poisoning results in an estimated 10,000 emergency department visits in Turkey annually and is one of the leading causes of poisoning death. In the study conducted in 2010, CO poisoning cases have been occurred mostly in Marmara Region including the province of Bursa [1].

Hyperbaric oxygen (HBO) therapy is a medical treatment method that aims to increase the level of dissolved oxygen in the tissues. HBO therapy is recommended in severe CO poisoned cases to prevent long-term and persistent neurocognitive dysfunction. The European Committee on Hyperbaric Medicine (ECHM) has recommend HBO therapy for every CO poisoned person who presents with altered consciousness, clinical neurological,cardiac, respiratory or psychological signs whatsoever the carboxyhaemoglobin level at the time of hospital admission (Type 1 recommendation, Level B evidence) [2].

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Day by day HBO therapy has been increasingly used in the treatment of CO poisoning in our country. First application of HBO therapy is recommended as soon as possible following diagnose, at most within 24 hours of onset [3]. Though early administration of HBO therapy is recommended, some clinicians could have limited accessibility to HBO therapy centers regionally.

The aim of this study is to evaluate the demographic characteristics, clinical and laboratory findings, treatments and results of patients who were administered HBO therapy due to CO poisoning in our clinic. Findings obtained regarding application of HBO therapy for patients with CO poisoning may provide clues that can be used in emergency patient management.

Materials and Methods

The study was conducted in accordance with the Declaration of Helsinki and was approved by the review board of the institution. The medical records of patients who were administered HBO therapy due to CO poisoning between September 2016, and August 2017, were reviewed.

The following information was extracted from medical records: demographic properties of patients, CO source, symptoms and signs, electrocardiography (ECG) findings, time between first admission to emergency department and HBO therapy, blood gas analysis, number of HBO therapy sessions and outcomes.

Each patient diagnosed with CO poisoning is treated with

normobaric oxygen via mask with reservoir bag in emergency department. If HBO therapy is prescribed for the patient's recovery, consultation is made with our HBO therapy unit. Those patients who were selected as an appropriate candidate, could referred to our HBO therapy unit.

The first HBO therapy for patients were administered immediately following their admission to HBO therapy clinic usually within the first hour or two of admission to emergency department. In the process of consultation made with emergency departments regarding the need for HBO therapy of patients with CO poisoning, final decision has based on ECHM recommendations.

Each session of HBO therapy lasted about 120 minutes, comprising three 25-minute oxygen periods at 2.4 atmospheres absolute (ATA), separated by five-minute air breaks, with compression and decompression in the remaining time. All therapies were administered in a multiplace hyperbaric chamber.

If carboxyhaemoglobin (COHb) level decrease below 5% in repetetive blood gas analysis or patients show no signs or symptoms, patients were sent back to the facility/department where they were referred after 1 session of HBO therapy. If patients' signs or symptoms do not regress totally after 1 session of HBO therapy, even if COHb level decrease below 5%, patients were scheduled to receive HBO therapy daily until reaching a total of 5 sessions in the following days. Patients with COHb<5% in blood gas analysis and show no signs or symptoms were considered to have recovery.

Since Thom et al suggested a "golden time" of 6 hours, the patients were investigated as divided into 2 groups as those who applied before 6 hours and those who applied later [4]. The patients were also investigated by dividing them into 3 groups: during working hours, after working hours and after midnight, considering the time of admission to ED.

Glasgow Coma Scale (GCS) score is a reliable method that aims to objectively evaluate the consciousness of patients [5]. GCS score can be used not only at the time of application but also for follow-up. Studies have shown that a low GCS score may be associated with mortality and intoxication severity, and can be used as an important marker in determining cardiac damage [6]. In this study, GCS scores of the patients were evaluated three times: on first admission to ED, before HBO therapy, and after HBO therapy or therapies. Considering GCS scores, the patients were investigated by dividing them into 2 groups like study of Pepe et al: abnormal (GCS≤14) and normal (GCS=15) [7].

The study data was analyzed with SPSS 21.0 software. Data were expressed as mean ± standard deviation (SD) or n (%). Differences in proportions and means between groups were analyzed using the chi-squared test, and Mann-Whitney U test, respectively. A p-value of <0.05 was accepted as statistically significant.

Results

During the period reviewed, a total of 127 patients with CO intoxication were treated with HBO therapy. Of these, 2 patients were excluded from analysis who experienced middle ear barotrauma and discontinued HBO therapy. Thus, 125 patients were evaluated in the study.

96 patients were referred in the winter months of December through February (76.8%) and 56 patients were between 16:00 and 24:00 hours (44.8%). The most frequent CO sources were heating systems including stoves (63 patients (50.4%)) and natural gas boilers (43 patients (34.4%)) [Table 1].

Table 1. Season, admission time and poisoning source distributions of CO poisonings

Season(n(%))	Autumn	19(15.2%)
	Winter	96(76.8%)
	Spring	10(8%)
Time of admission to ED(n(%))	08:00-16:00	53(42.4%)
	16:00-00:00	56(44.8%)
	00:00-08:00	16(12.8%)
CO source(n(%))	Stove	63(50.4%)
	Natural gas boiler/stove	43(34.4%)
	LPG boiler	12(9.6%)
	others	7(5.6%)

Mean age of the patients was 36 ± 21.8 years (0-89). 84 patients (67.2%) were female and four of them were pregnant. The most common complaints of the patients were the history of syncope (41.7%) and confusion (34.6%) seen in 53 and 44 patients, respectively. Abnormal ECG findings were observed in 42 patients. Patients' characteristics are presented in Table 2.

Table 2. Characteristics of patients treated with HBO therapy for CO poisoning

mean age(years)		35.9 ± 21.6
gender(n(%))		
female		84(67.2%)
male		41(32.8%)
signs&symptoms(n(%))	history of syncope	52(41.6%)
	confusion	44(35.2%)
	headache	20(16%)
	vertigo	4(3.2%)
	convulsion	2(1.6%)
	chest pain	1(0.8%)
	speech disorder	1(0.8%)
	nausea and vomiting	1(0.8%)
ECG abnormalities(n(%))	Yes	42(33.6%)
	No	58(46.4%)
	Not available	25(20%)

The distribution of abnormal ECGs was as follows: sinus tachycardia in 25 patients, right bundle branch block in 12 patients, atrial premature beat in 2 patients, and first-degree atrioventricular block in 3 patients.

Among all patients, 75 (60%) were from our institution, 35 (28%) were from other hospitals in Bursa and 15(12%) were from 3 other cities. The mean elapsed time between admission to emergency department and HBO therapy clinic admission was 3h ± 2h 29 min (range: 1–10 h). Eleven of the 15 patients referred from outside the province were able to reach our HBO therapy clinic after more than 6 hours. Only 8 of the 102 patients referred from the same facility or city's hospitals experienced such delay [Table 3] (p <0.01).

Table 4 shows that GCS of the patients increased both with oxygen therapy given in ED and after HBO therapy given in our clinic. 59 out of 77 patients with a GCS score of 9-14, which could be accepted as an indicator that patient have neurological impairment, increased the GCS score of 15 with normobaric oxygen therapy. Rest 18 patients increased the GCS score of 15 with HBO therapy.

Table 3. Distributions of patients' elapsed time between emergency admission and HBO therapy, and centers which were referred to for HBO therapy

	Same facility	Same city	Out of city	Total
0-1 hour	30	4	0	34
1-2 hours	33	8	0	41
2-3 hours	9	14	1	24
3-6 hours	0	4	3	7
6-12 hours	3	5	11	19
Total	75	35	15	125

Table 4. Distributions of patients' GCS scores at different times

	Admission to ED		Admission to HBO therapy unit		At discharge
3-8	81(64.8%)	5(4%)	23(18.4%)	5(4%)	0
9-14		76(60.8%)		18(14.4%)	0
15		44(35.2%)		102(81.6%)	124(99.2%)

14 of the 20 patients whose GCS≤14 had abnormal ECG findings when admitted to HBO therapy unit. Of the 80 patients with GCS=15, only 28 had abnormal ECG findings. This difference was found to be statistically significant ($p<0.01$).

The mean COHb level of the patients was 29.6% (range: 1.1%–57.1%) when emergency unit admission [Table 5]. While 25 of the patients (19,6%) evaluated in this study had a COHb level above 40%, which shows severe hypoxia, 39 of the patients (30.7%) have the COHb level of lower than 25%. In blood gas analysis of patients, mean lactate level was found 4.80±9.59 mmol/L and mean pH was 7.346±0.075.

Table 5. Results of patients' blood gas analysis

		Admission to ED	At discharge	p
COHb(n)	<25	39(31.2%)	124(99.2%)	
	25-40	62(49.6%)	0	
	>40	24(19.2%)	0	
Mean COHb(%)		29.62±11.70	3.72±3.14	p<0.01
Mean pH		7.346±0.075	7.356±0.044	p<0.05
Mean lactate (mmol/L. n=115)		4.80±9.59	1.52±0.83	p<0.01

When the number of HBO therapy sessions administered to patients was examined, it was observed that 1 session was administered to 114 patients (91.2%), and 2-5 sessions were administered to 11 patients (8.8%). The mean of HBO therapy sessions applied was 1.35. There was no relationship between the number of HBO therapy and either elapsed time before HBO therapy or the distance of the referral center.

Most of the patients treated with HBO therapy were discharged with recovery. One (0.8%) patient died due to CO poisoning. A 76-year-old patient with GCS=4 and with significant acidosis died on the first night of her admission to the ICU after the first HBO therapy. In this study, the mortality rate was found to be 0.8%.

Discussion

One of the most common poisonings in our country is CO poisoning and it is vital to treat it as soon as possible either with normobaric oxygen or HBO therapy. Although it is very undesirable for CO poisoned patients to be transferred out of the province under emergency conditions, this can happen in cases where there are a limited number of HBO therapy centers.

The seasonal profile in this study showed that CO poisoning cases were more prevalent in winter. A significant increase was seen in the incidence of CO poisoning during the colder months. The increase in the use of carbon-containing fuels for heating during the winter contributes to this result. A study in our country found that hospital admissions and deaths with diagnosis of CO poisoning increased during the winter months [1].

Since the vast majority of CO poisoning in our country is caused by equipment used for heating, poisoning usually occurs in the evening and night when temperature decreases. When patients noticed symptoms late, they could apply to in the early morning. In this study, the most frequent admissions of the patients were between 4:00 pm - 12:00 pm. Between these hours, the HBO therapy units have finished their routine work and have started to provide service as needed. For this reason, it is very important to plan the personnel who are expected to serve when necessary. Because they should be able to manage and treat the patient as soon as possible. This reaction is considered to be important in the prognosis of the patient. This data could be benefited in working plan of HBO therapy centers.

When CO source causing poisoning was examined, the majority of the cases were caused by the stove used by burning wood or coal. In our country, CO poisoning is generally caused by heating systems such as stoves and combi boilers, and suicide cases are very rare [8]. In developed countries, deaths due to exposure to CO gas for suicide are frequent [9]. In this study, there was no patient exposed to CO gas with the aim of suicide.

When elapsed time between admission to emergency department and HBO therapy was examined, the mean time was found 3 hours in this study. Similarly Maffi et al found that mean time of transfer from referring sites to the hyperbaric facilities was 200 minutes in Italy[10]. In this study, the distance of the referral center was found statistically significant for the accessibility of HBO therapy in the first six golden hours. This result confirm that distance and patient transfer opportunities should be considered when determining the places where HBO therapy centers are planned to be opened.

Hypoxia constitutes the most basic pathophysiological mechanism known in CO poisoning and the basic treatment approach is to give high dose of oxygen in a short time possible. Unfortunately, in patients who were evaluated would benefit from HBO therapy, tissue hypoxia will continue until the onset of therapy. Liao et al stated that the long duration before HBO therapy initiation was an independent determinant of the development of delayed neuropsychiatric sequelae(DNS), and concluded HBO therapy should be performed as early as possible and preferably within 22.5 hours [11].

In this study, it was determined that HBO therapy started on average 3 hours after the patients admitted to the emergency department. This period of time can be explained by the fact that our patients came from many external centers. Moreover our patients' general condition can be bad at the time of admission to the emergency department and in need of time to evaluation and stabilisation. Another explanation for this situation may be the delay of emergency department clinicians in noticing the need for HBO therapy.

This study verifies that patients of all ages could been safely administered HBO therapy with the diagnosis of CO poisoning [Table 2]. Interestingly, 67.7% of the patients were female, that proportion was higher than previous studies. In the studies, the distribution of age and gender varies of patients diagnosed of CO

poisoning. Because CO poisoning affects everyone in the same environment, regardless of age and gender. However, this does not mean that the prognosis of all age groups will be similar.

Unfortunately there are no symptom or sign that is diagnostic for CO poisoning. The most common symptom may differ in studies. In the study conducted by Arıcı et al., it was found that the most common symptoms in patients with CO poisoning who applied to emergency department were nausea-vomiting, loss of consciousness and headache [12]. In this study, it was determined that the most common symptoms were history of syncope and confusion (respectively 41,7% and 34,6%). The fact that the patients had more neurological symptoms in this study can be explained by the fact that the patients with more severe symptoms were selected for HBO therapy. This situation indicate that a group of patients who have neurological impairments, administration of HBO therapy contributes positively to the treatment.

In this study, patients whose GCS score were measured before HBO therapy were divided into 2 groups as GCS=15 and GCS≤14. The incidence of ECG abnormalities in patients GCS≤14 group was found to be higher than those with a GCS=15 group. This finding suggested that the GCS score might be effective in predicting cardiac damage. In our study, the lack of information about the long-term follow-up of the patients cause inadequate evaluation of the relationship between the GCS and DNS.

Findings of the this study were similar to previous studies that demonstrate that a CO-poisoned patient may sometimes have only a mildly elevated or even normal COHb level. In the presence of a low COHb level, the diagnosis of CO poisoning should not be dismissed if the anamnesis and clinical findings are appropriate [13].

Unless the COHb level is extremely elevated, it should be used as a confirmatory marker of exposure and not a gauge of severity of CO poisoning. The severity of poisoning should be based upon factors that reflect the effect of the poisoning, such as neurologic and cardiac status. To date clinical studies like this, have found no relationship between COHb level and patient presentation [14].

In patients with CO poisoning, there is an increase in lactate level as a result of tissue hypoxia and anaerobic glycolysis. High lactate level is an important indicator of tissue hypoxia. Moon et al. stated that lactate level was an independent factor associated with serious complications and the need for intensive medical treatment in patients with CO poisoning [15]. In another study conducted by İcme et al., of 201 patients of CO poisoning, it was found that the blood lactate level was higher in patients who received HBO therapy and had a GCS<15. The authors suggested that blood lactate level and COHb level could be used together in foreseeing HBO therapy requirement [16].

In conclusion, CO poisoning is still a serious health problem for our country. Paying a high level of attention, especially in the autumn and winter seasons, may cause a decrease in the number of cases. The clinical presentation of patients may not always correlate with COHb levels. Decreased GCS score of patients may be a stimulus for cardiac involvement. Wide spreading the HBO therapy centers that may service in emergencies can be recommended to provide faster access of patients.

Because this was a retrospective study, CO exposure time and the treatment given before hospital couldn't be evaluated. Also the absence of long term follow up is a limitation for this study.

Conflict of interests
The authors declare that they have no competing interests.

Financial Disclosure
All authors declare no financial support.

Ethical approval
TApproval was obtained from the clinical research ethics committee of Bursa Yuksek Ihtisas Training and Research Hospital.

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