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Carbon monoxide poisoning in children – own observations**

Zatrucie tlenkiem węgla u dzieci – własne obserwacje

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S u m m a r y

Introduction. Carbon monoxide (CO) is a colorless, odorless gas produced at an incomplete combustion of carbonaceous compounds. CO inhalation is the most common cause of poisoning in the industrialized world.

Aim. Analysis of epidemiological and clinical data of children hospitalized due to carbon monoxide poisoning.

Material and methods. The medical records of 36 consecutive children aged between 8 months and 18 years (average 7 years 8 months) admitted to the Department of Pediatrics in Warsaw from January 2003 through October 2012 with CO poisoning were reviewed.

Results. Of these 36 cases, 22 (61%) were caused by a faulty gas heater, 7 (19.5%) by a fire, 6 (16.7%) by faulty ventilation, and in one case (2.8%) it was not possible to determine the cause. In 12 (33.3%) children no symptoms were observed, while in certain children a number of symptoms was present. Most frequently, in as many as half of the cases, the symptoms were drowsiness/lethargy, followed by headache, syncope, vomiting and nausea. The carboksyhemoglobin (COHb) levels in all children ranged from 2.0 to 33.1% (average 13.3%). In 9 (25%) children it was necessary to administer HBO treatment. In this group, the COHb levels ranged from 11.0 to 33.1% (average 25.3%). Abnormal results of laboratory tests occurred in 3 children with COHb levels of 11%, 20% and 30.6%. In all of them it was an elevation of CK-MB, to the level of 2.38, 11.94 and 2.8 ng/ml respectively.

Conclusions. Carbon monoxide poisonings are most common in the autumn-winter period. This type of poisoning can be confirmed by determining the carboksyhemoglobin level. Overall, the range of the COHb levels was relatively broad and showed no relationship with the symptoms. The most important intervention is to provide the victim adequate treatment, in the form normobaric oxygen or hyperbaric therapy.

Key words: carbon monoxide poisoning, children, hyperbaric oxygenation

S t r e s z c z e n i e

Wstęp. Tlenek węgla (CO) jest bezbarwnym gazem bez zapachu wytwarzanym z niepełnego spalania związków węglowych. Wdychanie CO jest najczęstszą przyczyną zatrucia w krajach uprzemysłowionych.

Cel. Analiza danych epidemiologicznych i klinicznych dzieci hospitalizowanych z powodu zatrucia tlenkiem węgla.

Materiał i metody. Poddano analizie dokumentację medyczną 36 dzieci w wieku od 8 miesięcy do 18 lat (średnio 7 lat 8 mies.), hospitalizowanych w Klinice Pediatrii w Warszawie od stycznia 2003 do października 2012 roku z powodu ostrego zatrucia CO.

Wyniki. Spośród 36 dzieci u 22 (61%) przyczyną zatrucia CO były uszkodzone grzejniki gazowe, u 7 (19,5%) pożar, u 6 (16,7%) uszkodzona wentylacja, a w jednym (2,8%) przypadku nie udało się określić przyczyny. U 12 (33,3%) dzieci nie stwierdzono żadnych objawów, zaś u niektórych występowało kilka. Najczęściej, bo aż w połowie przypadków, była to senność i ospałość, następnie ból głowy, omdlenia, wymioty i nudności. Poziom hemoglobiny tlenkowęglowej (COHb) u dzieci wynosił od 2,0 do 33,1% (średnio 13,3%). U 9 (25%) dzieci konieczne było zastosowanie leczenia w komorze hiperbarycznej (HBO). W tej grupie poziom COHb był od 11,0 do 33,1% (średni 25,3%). Odchylenia w badaniach laboratoryjnych występowały u trójki dzieci z poziomem COHb 11%, 20% i 30,6%. U wszystkich było to podwyższenie CK-MB odpowiednio 2,38, 11,94 i 2,8 ng/ml.

Wnioski. Do zatruć tlenkiem węgla dochodzi w okresie jesienno-zimowym. Badaniem potwierdzającym zatrucie jest oznaczenie karboksyhemoglobiny. Zakres poziomów COHb był dość szeroki i nie wykazywał związku z objawami. W leczeniu najistotniejsze jest jak najszybsze zapewnienie poszkodowanemu odpowiedniego leczenia, pod postacią tlenoterapii biernej lub w komorze hiperbarycznej.

Słowa kluczowe: zatrucie tlenkiem węgla, dzieci, tlenoterapia hiperbaryczna

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INTRODUCTION

Carbon monoxide (CO) is a colorless, odorless gas produced at an incomplete combustion of carbonaceous compounds. CO inhalation is the most common cause of poisoning in the industrialized world. Severe CO poisoning may cause multi-organ dysfunction, frequently necessitating an admission to intensive care units. CO poisoning is frequently unrecognized, because the signs and symptoms are relatively nonspecific (1). In the United States National Poison Data System (NPDS), the reported mortality rates caused by this type of poisoning range between 1% and 31% of all deaths. Most CO exposures occurred at home and most often involved females, children aged ≤ 17 and adults aged 18-44. Clinical symptoms were reported for 68.1% of the total exposures, with headache, nausea and dizziness observed most commonly (2).

The administration of supplemental O_2 is the cornerstone in the treatment of CO poisoning. Oxygen inhalation will accelerate the dissociation of CO from hemoglobin, as well as provide enhanced tissue oxygenation. Hyperbaric oxygen therapy (HBOT) is a treatment modality in which a person breathes 100% O_2 while exposed to an increased atmospheric pressure (3).

In our study, we have reviewed the symptoms and the results of hyperbaric oxygen therapy (HBOT) in the treatment of 36 children with CO poisoning.

AIM

Analysis of epidemiological and clinical data of children hospitalized due to carbon monoxide poisoning.

MATERIAL AND METHODS

The medical records of 36 consecutive children, 12 (33.3%) girls and 24 (66.7%) boys, aged between 8 months and 18 years (average 7 years 8 months), admitted to the Department of Pediatrics in Warsaw from January 2003 through October 2012 due to CO poisoning, were reviewed. Every year, one (2004, 2008, 2010) to eight children (2007, 2012) were hospitalized. Most of the children, as many as 29 (80.5%), were hospitalized during the autumn-winter months (from October to March) (fig. 1). No patients were excluded from the study. Nine of them (25%) were referred to the hyperbaric unit for treatment.

The COHb levels were measured at the local laboratory from venous blood.

RESULTS

Of these 36 cases, 22 (61%) were caused by a faulty gas heater, 7 (19.5%) by a fire, 6 (16.7%) by faulty ventilation, and in one case (2.8%) it was not possible to determine the cause. Table 1 presents the symptoms of the children exposed to carbon monoxide. In 12 (33.3%) children no symptoms were observed, while in certain children a number of symptoms occurred. In most cases, that is in as many as half of the cases, the symptoms were drowsiness/lethargy, followed by headache, syncope, vomiting and nausea.

Table 1. Symptoms in the children exposed to carbon monoxide.

Symptoms (n = 59) Children (n = 36)	No.	(%)
Observed symptoms of poisoning	24	66.7%
Drowsiness/lethargy	12	50.0
Headache	10	41.7
Syncope	8	33.3
Dizziness/vertigo	7	29.2
Vomiting	7	29.2
Nausea	3	16.7
Abdominal pain	2	8.3
Redness of the skin	2	8.3
Balance disorders	2	8.3
Confusion	1	4.2
Chest pain	1	4.2
Visual disturbances	1	4.2
Other	3	12.5
Without symptoms of poisoning	12	33.3%

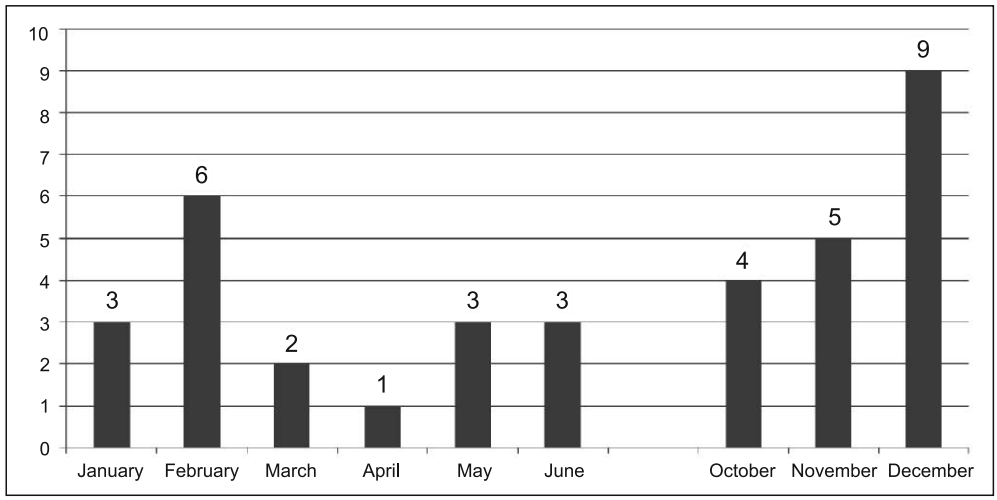

Fig. 1. Hospitalizations due to CO poisoning depending on the date of admittance.

In five (13.9%) children an elevated level of white blood cells was observed, in four cases occurred an elevated level of cardiac creatine kinase (CK-MB, 2.38-11.94 ng/ml), in one case an increase of troponin was observed, and in one case an elevated level of glucose occurred. In one child the electrocardiogram (ECG) recorded a increase of the ST in the V2-V3 leads. In 27 (75%) cases no abnormalities were reported in laboratory tests and in ECG.

The carboksyhemoglobin (COHb) levels in all children in the study were from 2.0 to 33.1% (average 13.3%). In 9 (25%) children it was necessary to administer/introduce HBO treatment. All the children referred for HBO were treated in the chamber. In this group, the COHb levels ranged from 11.0 to 33.1% (average 25.3%). Two children received one HBOT treatment, two children – two, and five children – three treatments. In 24 children (66.7%) the exclusive treatment was passive oxygen therapy. In this group, the COHb levels ranged from 2.0 to 22% (average 16.5%). In three children whose COHb levels were 3% no treatment was administered.

In three (8.3%) children with COHb levels above 30% (moderate-severe poisoning) the dominant symptom was syncope. In one of them, also vomiting and major convulsions occurred. After the return of consciousness, all children suffered from headaches, and in individual cases the above symptoms were accompanied by confusion, drowsiness and weakness. All of these patients were administered hyperbaric chamber treatment (two to three times), which was followed by passive oxygen therapy.

In 15 (41.7%) children, the COHb levels did not rise above 10%, and the symptoms of poisoning were mild. The most frequently reported symptoms were vomiting, abdominal pain, headache and excessive drowsiness. However, considering the fact that most of the poisoning occurred at night, the drowsiness was misinterpreted by the adults. Also vomiting and abdominal pain suggested an acute gastroenteritis to the family. An example here may be the CO poisoning of two sisters who were moved to another room after their mother was observed to have lost her consciousness. Only after a certain time it was noticed that they did not wake up despite the chaos and noise in the room. The COHb levels in these girls were 9.4% and 8.4% respectively. They were administered passive oxygen therapy treatment.

In the children who were reported to show no symptoms of carbon monoxide poisoning the suspicion of this condition was made based on the clinical history. Six out of the seven children were victims of a fire, and the remaining one was a witness of his father's carbon monoxide intoxication.

Out of the 18 (50%) children with COHb levels ranging from 10 to 30% (mild poisoning), no symptoms were observed in five of them. In five other children, non-specific symptoms occurred, such as nausea, vomiting, headaches. A syncope took place in four children from among six in whom the COHb levels ranged between 20 to 30%. In five children from the latter group it was necessary to administer the hyperbaric chamber treatment. In one case (COHb at the level of 22%) passive oxygen therapy was applied with a good result. The symptoms of the children according to their level of carbon monoxide are presented in table 2.

It is worth mentioning that in one case a boy was hospitalized twice due to carbon monoxide poisoning within the period of one month, which is an example of carelessness of his parents. At the first admittance, his COHb level was 4%, and the only symptom was a difficulty with walking. However, the parents ignored the fact that the intoxication was caused by a faulty gas heater. After a month, the boy was admitted to hospital again, with severe symptoms of poisoning (syncope), with an COHb level of 28.3%. The boy received

Table 2. Symptoms of the children according to the level carbon monoxide.

Symptoms (n = 59) Children (n = 36)	**COHb < 10% (n = 15) symptoms = 16**	**COHb 10-30% (n = 18) symptoms = 32**	**COHb > 30% (n = 3) symptoms = 11**
Drowsiness/lethargy	2	8	2
Headache	2	5	3
Syncope	1	4	3
Dizziness/vertigo	2	4	1
Vomiting	4	2	1
Nausea	–	3	–
Abdominal pain	2	–	–
Redness of the skin	–	2	–
Balance disorders	1	1	–
Confusion	–	–	1
Chest pain	–	1	–
Visual disturbances	1	–	–
Other	1	2	–
Without symptoms	7	5	–

only one HBOT treatment, because due to his primary condition (the Down syndrome) he did not tolerate the treatment in a chamber.

Out of the 9 children who were administered HBOT treatment, in 8 cases the COHb levels were above 20%, and in one it was 11% (average 25.3%). Among this group of patients, the dominant symptoms were drowsiness, lethargy, syncope, headaches, vomiting (tab. 3). Abnormalities in laboratory tests were observed in three children with COHb levels of 11%, 20% and 30.6%. In all three it was an elevation of CK-MB of 2.38, 11.94 and 2.8 ng/ml respectively. In one child with a COHb level of 20% also an elevation of troponin (0.069 ng/ml), glucose and white blood cells was observed.

Table 3. Symptoms of COHb poisoning in children treated with HBO.

Symptoms (n = 30) Children (n = 9)	COHb 11-33.1% (mean 25.3%)
Drowsiness/lethargy	7
Headache	6
Syncope	6
Dizziness/vertigo	3
Vomiting	3
Nausea	2
Abdominal pain	–
Redness of the skin	1
Balance disorders	–
Confusion	1
Chest pain	–
Visual disturbances	–
Other	1
Without symptoms	–

Significantly, despite the fact that at the homes of certain patients the gas heater was only present in the bathroom, the highest CO concentration was observed in other rooms (the kitchen) as a result of faulty ventilation.

DISCUSSION

The symptoms of CO poisoning are non-specific, and are thus frequently misdiagnosed. CO can affect multiple organ systems, but the central nervous system and the cardiovascular system are affected most severely due to their high oxygen requirement. With acute exposure to high CO concentrations, patients may quickly lose consciousness. It is more typical, however, for patients to report non-specific symptoms, such as headache, nausea and dizziness.

In our material, the symptoms of drowsiness/lethargy occurred in half of the children, while headache, syncope, dizziness/vertigo and vomiting were observed in 30-40% cases.

A correlation of 2 to 10% exists between the development of symptoms such as headache and dizziness and the COHb levels (4, 5). Unfortunately, no reliable correlation exists for more severe signs and symptoms and the COHb level. The absence of objective measures for establishing the severity of CO poisoning remains among the most troublesome aspects of clinical evaluations. Normal COHb levels are less than 3% (up to 10% in a current smoker). The COHb level on admission to hospital depends on multiple factors related to the time and the course of the exposure, the rescue and the treatment – and therefore may not correlate with the severity of the symptoms (6).

In 33.3% of the cases considered in the study, no symptoms were reported despite the COHb levels exceeding 3%. Also, no symptoms occurred in 5 children with COHb levels between 13 and 18%. However, in one 12.6-year-old boy severe symptoms of poisoning occurred with the COHb level of 11%. The symptoms were dizziness, headache, drowsiness, vomiting. An elevated level of CK-MB was also reported in the boy. He required three HBOT treatments.

Not only are the symptoms and signs of CO poisoning non-specific, but also the initial investigations may be misleading. A definitive diagnosis of a CO poisoning can be made based on the observed elevated levels of COHb, measured in either arterial or venous blood with a CO oximeter. At our department, all children had the measure of their venous blood COHb levels performed at the local laboratory.

All patients were also determined in blood cell count, glucose, urea, creatinine, cardiac enzymes, alkaline phosphatase, aminotransferase, lactate dehydrogenase. Among children hospitalized in our department leucocytosis was diagnosed in 5 (13.9%), elevated level of CK-MB in 4 (11.1%), elevated level of troponin in 1 (2.7%) and 1 patient had changes in ECG (elevated ST in V_2, V_3 leading). None of the hospitalized children's did not require specialist treatment.

Many victims of CO poisoning are initially treated at hospitals without hyperbaric facilities, and often a decision must be made as to whether the patient should be transferred for O_2 treatment. The use of HBO is controversial, and if it is used, HBO should be applied for patients with severe symptoms, high COHb levels or pregnancy (7).

In our patients, we always used oxygen therapy, and with COHb levels above 10% with accompanying symptoms of poisoning, we always consulted the treatment with HBOT specialists. In our conditions, transporting the patient to the HBOT center took relatively little time and lasted less than half an hour.

The overall complication rate of HBOT is approximately 2 to 3%. The major risks of O_2 are barotrauma and O_2 toxicity (7). After recently evaluating 6 randomized controlled trials, the authors of a Cochrane review concluded that the existing evidence does not establish whether the administration of HBO for CO poisoning reduces the incidence of adverse neurologic outcomes (8).

In our nine patients who were administered HBOT treatment, no early complications were observed. How-

ever, it must be noted that we did not conduct observations that would last a few years; thus, we are not able to discuss any long-term effects of this treatment.

Patients at the time of discharge from hospital did not have any symptoms of carbon monoxide poisoning. Due to the lack of contact with patients we are not able to assess frequency of delayed neurological syndromes in patients treated with HBO therapy and breathing 100% oxygen.

The administration of supplemental O_2 is the cornerstone in the treatment of CO poisoning. Oxygen inhalation accelerates the dissociation of CO from hemoglobin, as well as provides enhanced tissue oxygenation. The pre-hospital management of CO poisoning entails an immediate removal of the patient from the CO environment and treatment with 100% O_2.

In this context, the fact that the parents ignored the first symptoms of CO poisoning in one of our patients and did not repair the faulty gas heater raises serious concerns. On the other hand, because the symptoms of CO poisoning are initially non-specific, it is possible that they are be ignored by the parents and others.

The months with the highest proportion of poisoning incidents were November, December and January (9). The prevention of CO poisoning must focus on its epidemiology. What is also significant, most of the children with CO poisoning were hospitalized at our department in the autumn-winter months (with a peak in December and February). Thus, it is especially vital that the services responsible for the proper functioning of gas appliances and ventilation in the houses are effective before the heating season begins.

To sum up, it should be generally noted that the range of the COHb levels in all patients was relatively wide and showed no relationship with the patients' level of consciousness. CO remains an environmental threat causing significant morbidity and mortality in children.

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