Pomeranian J Life Sci 2017;63(3):95-100

Delayed neurological sequelae in carbon monoxide poisoning – a case report and present state of knowledge

Opóźnione następstwa neurologiczne w zatruciu tlenkiem węgla – opis przypadku i aktualny stan wiedzy

Dariusz Kotlęga[1, 2] ✉, Barbara Peda[2], Monika Gołąb-Janowska[1], Przemysław Nowacki[1]

[1] Pomorski Uniwersytet Medyczny w Szczecinie, Katedra i Klinika Neurologii, ul. Unii Lubelskej 1, 71-252 Szczecin
[2] Głogowski Szpital Powiatowy, Oddział Neurologii, ul. Kościuszki 15, 67-200 Głogów
✉ dkotlega@poczta.onet.pl

ABSTRACT
Introduction: Carbon monoxide (CO) is one of the most common causes of fatal gas poisoning through the airways mainly due to central heating faults. Carbon monoxide inhibits oxygen transport by binding to haemoglobin and the formation of carboxyhaemoglobin. The neuropsychological symptoms of poisoning are defined as delayed neurological sequelae and usually occur after a lucid interval.
Case report: We present a patient with neurological symptoms that occurred 27 days after acute poisoning that had been treated with the use of hyperbaric oxygen therapy. On examination the patient was in a mutism-like state, had severe cognitive disorders, hypomimia, bilateral limb stiffness, increased deep tendon reflexes, bilateral Babinski sign and sphincter incontinence. The brain magnetic resonance imaging showed diffused bilateral hyperintensities in the white matter with additional lesions in semioval centres. She was treated with amantadine infusions, sertraline, levodopa and piracetam with gradual improvement. Besides neurological improvement the outcome was fatal. In our patient the initial Glasgow Coma Scale score was 7 points, and leukocytosis and troponin increase were detected. These results might be potentially used as prognostic factors in the course of the observed neurological symptoms.
Conclusions: Further studies should be performed for a better understanding of delayed neurological sequelae pathogenesis aiming at the prevention or effective treatment of this significantly disabling disorder.
Keywords: delayed neurological sequelae; carbon monoxide; intoxication; encephalopathy; treatment.

ABSTRAKT
Wstęp: Tlenek węgla (CO) jest jedną z najczęstszych przyczyn śmiertelnego zatrucia poprzez drogi oddechowe, spowodowane głównie niesprawnością urządzeń grzewczych. Tlenek węgla prowadzi do hamowania transportu tlenu przez połączenie z hemoglobiną i utworzenie karboksyhemoglobiny. Objawy neuropsychologiczne określane jako opóźnione następstwa neurologiczne zatrucia pojawiają się zwykle po okresie przejaśnienia.
Opis przypadku: Objawy neurologiczne pojawiły się 27 dni po zatruciu tlenkiem węgla leczonym terapią hiperbaryczną. W badaniu stwierdzono objawy mutyzmu, znaczne zaburzenia poznawcze, hipomimię, obustronną sztywność kończyn, wzmożone odruchy głębokie, obustronnie objaw Babińskiego i nietrzymanie zwieraczy. W badaniu rezonansem magnetycznym mózgowia zaobserwowano rozlane zmiany hiperintensywne obustronnie w istocie białej i w środkach półowalnych. W leczeniu stosowano wlewy amantadyny, sertralinę, lewodopę oraz piracetam, uzyskując stopniową poprawę. Pomimo poprawy stanu neurologicznego zachorowanie skończyło się zgonem. Początkowy wynik w skali Glasgow wyniósł 7 pkt, obserwowano leukocytozę, podwyższony poziom troponiny. Wyniki te mogą być potencjalnie wykorzystane jako czynniki predykcyjne rokowania w przebiegu obserwowanych objawów neurologicznych.
Wnioski: Kolejne badania powinny mieć za cel lepsze poznanie patogenezy powikłań neurologicznych w przebiegu zatrucia CO w celu prewencji i skutecznego leczenia schorzenia, które powoduje istotną niepełnosprawność.
Słowa kluczowe: opóźnione następstwa neurologiczne; tlenek węgla; zatrucie; encefalopatia; leczenie.

INTRODUCTION

Carbon monoxide (CO) is an odourless gas and is one of the most common causes of fatal poisoning through the airways. The source of CO is the incomplete combustion of carbon-containing fuels, but in practice most accidents are caused by central heating faults. As a result of exposure to CO oxygen transport is inhibited due to a competitive binding to haemoglobin into carboxyhaemoglobin (COHb) [1, 2]. In the heating season 2015/2016 in Poland there were 3,878 cases of exposure to CO, with 2,229 injured and 50 deaths [3]. Neurological symptoms may be both acute and delayed, with clinical presentation depending on the severity and duration of the exposure to CO [4]. With regard to COHb concentration, different symptoms appear, such as headache, malaise, shortness of breath (10–20% COHb), vertigo, consciousness disturbaces, muscle

weakness (20–30% COHb), and death within minutes (60–70% COHb) [5]. Of note is that the average level of COHb in healthy individuals is about 1%, 5% in pregnancy and haemolytic anaemias, and up to 15% in heavy smokers [2, 6].

Neuropsychological sequelae appear after recovery from acute poisoning and are present in 2.75% of poisoned patients. Onset is preceded by a lucid interval lasting from 2 days to 26 weeks [7, 8, 9]. The most common symptoms are the persistent akinetic state with mutism, seizures, disorders of consciousness, behaviour and personality changes, apathy, gait disturbances, incontinence, movement disorders, behavioural and cognitive impairment with possible improvement, progressive course, relapses or even death in about 13% of cases. There is also a decline in attention, visuospatial organization, executive system functions, cognitive processing speed, psychomotor abilities, and reaction time [10]. Classically, clinical symptoms are divided into two main categories: parkinsonism or akinetic-mutism. In addition to characteristic parkinsonian motor features (mask face, rigidity, short-stepped gait, tremor), symptoms such as dystonic posturing, agitation, apathy, hallucinations, or odd behaviours may also be present. Verbal responses are very slow, with varying degrees of impaired cognition or emotional liability. Akinetic-mute patients are profoundly apathetic and develop functional bowel and bladder incontinence, and pathologic laughter or crying. Common findings on examination may include frontal release signs (e.g. snout, glabellar) and corticospinal tract signs. Early on, cognitive symptoms are so profound that detailed testing is difficult to obtain [9, 11, 12]. Less common symptoms are supranuclear gaze palsy, peripheral neuropathy and choreoatetosis [13, 14].

The complex clinical symptomatology results from the main involvement within the white matter, which is an essential part of the human brain and consists of clusters of myelinated axons linking neurons in various brain regions. Myelin increases the speed of impulse conduction through the axons in the nervous system and can be regulated by impulse activity. White matter structure is dynamic and is implicated in cognitive development, learning skills, information-processing, and working memory. Myelin is involved in cognition, learning, development of skills and memory. Abnormalities in myelin genes and toxic changes in the integrity of white matter structure cause slowed and desynchronized impulse traffic between distant cortical regions and contribute to the disorders of cognitive ability, thinking, mood, hallucinations, and neurological and psychological dysfunction. Myelin damage can also lead to paralysis, sensory-motor dysfunction, mental retardation and death [15]. White matter hyperintensity volume has been described in association with episodic memory and executive function impairment. Changes in bilateral temporal-occipital and right parietal periventricular white matter are responsible for episodic memory disorders, whereas changes in bilateral inferior frontal white matter, bilateral temporal-occipital, right parietal periventricular white matter and the anterior limb of the capsule bilaterally are responsible for lower executive functions [16].

CASE REPORT

Patient description

A 62-year-old female patient was admitted to the Neurology Department due to strange behaviour since the day before. These changes gradually increased during that day.

In the medical history there was carbon monoxide poisoning 28 days before the present admission with subsequent coma, intubation and oxygen hyperbaric treatment (COHb concentration before therapy was 24.8%). Other selected initial laboratory tests are presented in Table 1. After two courses of hyperbaric treatment the patient was awake with gradual improvement of consciousness. Another complication that occurred 2 days after the intoxication was myocardial infarct with decreased ejection fraction (35–40%) and heart relaxation. After 8 days of treatment in a cardiology department the patient was discharged in good general condition and without disturbances of consciousness.

On admission to the Neurology Department the patient had just slight contact disturbances with slight bradyphrenia and bradykinesia. Initial brain computed tomography (CT) was normal, and additional laboratory tests did not reveal any abnormalities. Two days after admission a sudden worsening of contact appeared. The patient was awake, in a mutism-like state, responding just using single words with a delay, obeying partially just single, simple commands. The patient had swallowing difficulties due to executional disturbances, which demanded a feeding tube insertion. At this time hypomimia appeared together with bilateral limb stiffness, increased deep tendon reflexes, bilateral Babinski sign and sphincter incontinence.

The neuropsychological assessment showed significant decline in the cognitive functions of the patient, memory impairment, anterograde amnesia, visuospatial functions impairment, adynamia, passivity, and aspontaneity. In this situation contact with the patient was difficult to obtain. She was not able to complete any of the standardized neuropsychological tests. The examination was based on clinical experiments and observation. The patient was characterized by a significant lack of verbal and motor spontaneity, psychomotor retardation, and lack of initiative. She was unable to perform her normal self-care activities or fulfil daily needs. External stimulation, prompts and commands could invigorate her to action temporarily, whereas lack of stimulation made her passive. Psychomotor impairment caused slowing down of thoughts, cognitive processing speed, reaction times, emotional reactions and speech. Spontaneous speech was abolished. Usually, there were no answers to open questions. Other answers were very short, usually one- or two-word answers with intact articulation and comprehension.

During the hospital stay the patient received drugs that affected the central nervous system, such as amantadine infusions in a daily dose of 400 mg for 10 days, sertraline, levodopa, and piracetam. During the 20-day hospitalization some improvement was observed. The patient responded to a greater extent, muscle tone decreased partially, and at the end of hospitalization she was able to stand with the assistance

of a physiotherapist, but no spontaneous gait activity was observed. Eighteen days after the termination of the hospital stay the patient died due to acute renal failure.

Additional tests results

The results of laboratory tests performed at the onset are presented in Table 1.

TABLE 1. Initial laboratory tests' results during an acute poisoning

Parameter	Value
Leukocytes	13.18 G/L
pH	7.448
Erythrocytes	4.18 T/L
Hemoglobin	13.7 g/dL
Platelets	263 G/L
Creatine kinase-MB	23.9 U/L
Creatine phosphokinase	517 IU
Glasgow Coma Scale	7 points
C-reactive protein	11.13 mg/L
Troponin T	0.062 ng/mL
Creatinine	0.86 mg/dL
Blood glucose	148 mg/dL

A spinal tap was performed with normal cerebrospinal fluid analysis. In a further investigation electroencephalography – EEG (Fig. 1) and brain MRI (Fig. 2–4) were done. The brain magnetic resonance imaging –MRI showed a generalized increase in signal in the white matter in T2-weighted and FLAIR scans with additional bilateral irregular hyperintense foci in the semioval centres with predominance on the right. No gadolinium enhancement was noticed.

The EEG showed irregular, high-amplitude record with alpha, beta and theta waves in the occipito-temporal and occipito-parietal areas. More evident bilateral theta waves were observed in frontal areas. No epileptiform discharges were noticed.

DISCUSSION

We present a case report showing the current state of knowledge regarding delayed neurological complications after CO poisoning. A patient underwent hyperbaric oxygen treatment the same day with significant clinical improvement, but the onset-to-treatment time was not precisely known, because the patient was found unconscious in the morning, having been seen for the last time the day before. The time-window within which hyperbaric oxygen is most effective has not yet been established. In one large retrospective study it was ineffective if started after 6 hours [17]. This type of treatment is nowadays a first-line treatment as hyperbaric oxygenation (HBO) therapy decreases COHb levels, restores tissue oxygenation, mitochondrial function and cellular energy metabolism, but even transient exposure to high concentrations of CO may cause brain injury acutely or within days to weeks. Hyperbaric oxygenation therapy is especially advised for patients with transient or prolonged episodes of loss of consciousness, abnormal neurological signs,

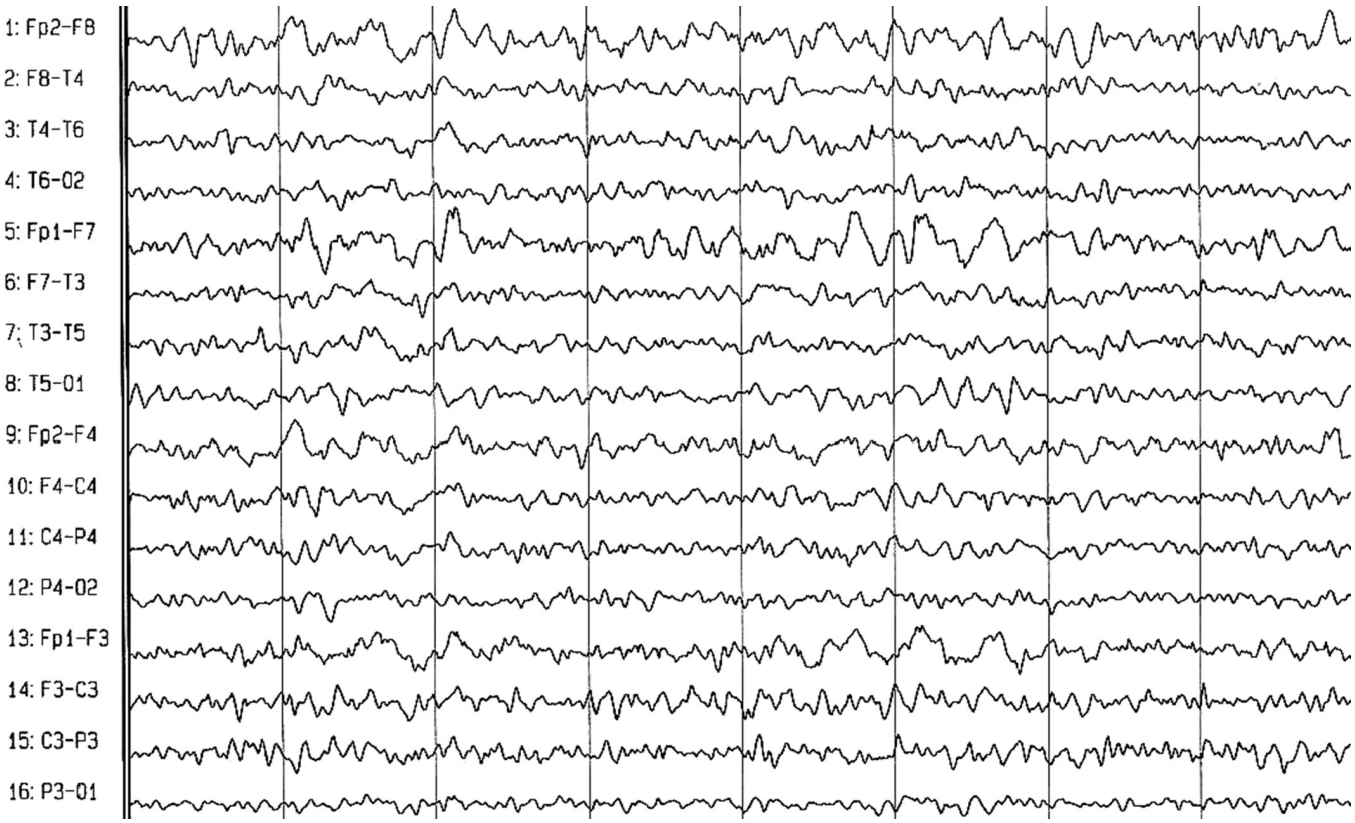

FIGURE 1. The electroencephalography record

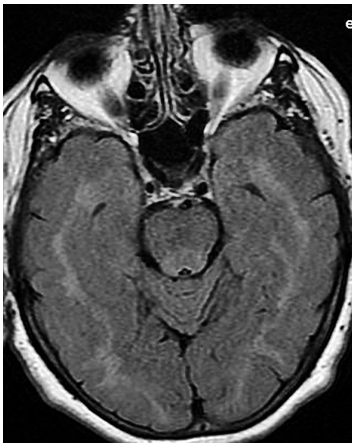

FIGURE 2. Brain magnetic resonance imaging presenting the hyperintense signal in the white matter bilaterally (FLAIR scan)

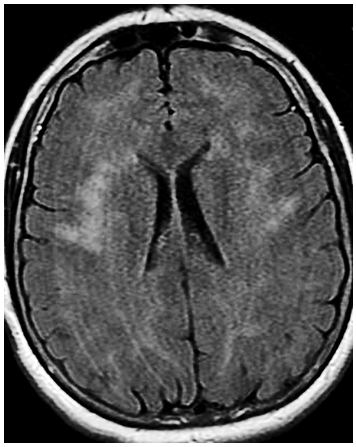

FIGURE 3. Brain magnetic resonance imaging presenting the hyperintensities in the semioval centres (FLAIR scan)

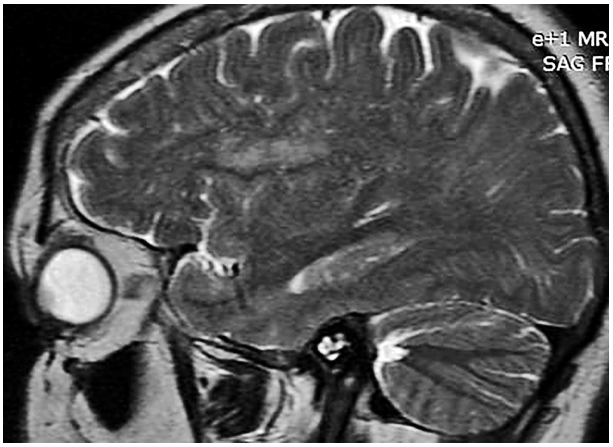

FIGURE 4. Brain magnetic resonance imaging presenting the hyperintense signal in the white matter (T2-weighted, sagittal scan)

cardiovascular dysfunction, severe acidosis, patients who are 36 years or older, pregnant women, when exposed for more than 24 hours, or those who have COHb levels of 25% or more [4].

Of note is the fact that the first analyses of HBO treatment in preventing neurological complications did not show significant efficacy, but further studies indicated such a possibility [18, 19]. According to the newest systematic review published in 2011, there were no available data to establish whether HBO treatment in CO-intoxicated patients reduces the incidence of neurological sequelae as there were limited numbers of high quality papers, as well as the methodological and statistical heterogeneity [20]. Moreover, HBO may also have potential neurological complications, such as hearing loss or seizures [21].

In our patient we found severe cognitive disability with bilateral pyramidal and extrapyramidal symptoms. The patient was staying in bed, because of the lack of spontaneous activity, but at the end of hospitalization she was able to stand with assistance. First symptoms of delayed neurological sequelae (DNS) appeared 27 days after the intoxication. Delayed neurological sequelae usually develop in patients with a mean age of 45.8–56.1 years. The lucid interval before appearance varies from 2 days to 26 weeks, but parkinsonism develops within 1 month after intoxication in the majority of patients. The most frequent symptoms are mental deterioration, urinary or faecal incontinence, gait disturbance and mutism. The most frequent signs are hypokinesia, masked face, glabella sign, grasp reflex, increased muscle tone, short-step gait, and retropulsion. Intentional tremor may occasionally be found, but resting tremor is not observed. There are no factors increasing the risk of DNS incidence except age and the severity of anoxia. There is no correlation between the neuroimaging findings and the development of parkinsonism. Previous associated diseases do not hasten the development of sequelae [7, 8, 9]. Possible prognostic factors for the development of DNS in patients with severe CO poisoning are serious disorders of consciousness or loss of consciousness at emergency admission, low Glasgow Coma Scale (GCS) score, head CT findings indicating hypoxic encephalopathy, haematology findings including high troponin, creatine phosphokinase, creatine kinase-MB and lactate dehydrogenase levels, low Global Assessment Scale scores, and intubation requirement [22, 23]. Other factors that may be associated with increased risk of DNS development are: CO exposure duration >6 hours, GCS score <9, seizures, systolic blood pressure <90 mmHg and leukocytosis, but in the multivariate analysis the independent factors were only the GCS <9 (OR 7.15; CI 95%: 1.04–48.8) and leukocytosis (OR 3.31; CI 95%: 1.02–10.71) [24]. From the abovementioned factors we found in our patient only the GCS score <9 points, leukocytosis and troponin increase as the initial factors potentially affecting the risk of DNS development.

In an analysis of 36 patients followed up for 2 years, 27 (75%) recovered within 1 year. In a study of 16 patients with parkinsonism followed up for 1 year, 13 (81.3%) recovered spontaneously within 6 months [7, 8]. Other authors reported that about 60–75% of patients with DNS recover within a year and about 15% continue to suffer from dementia and Parkinsonism. Poor outcome was seen in patients who had cardiorespiratory arrest or evidence of persisting basal ganglia hypodensities on CT scan and MRI hyperintensities in pallidum or white matter [25, 26]. More advanced neuroimaging tests may be of importance in the assessment and risk stratification regarding DNS. The presence of a lactate peak was a predictor for a poor long-term outcome in proton magnetic resonance spectroscopy – (1)H-MRS [27]. Full clinical correlation with radiological findings regards the MRI and SPECT studies, without such utility of CT [28].

The laboratory tests of myelin basic protein (MBP) levels in the cerebrospinal fluid can serve as a sensitive predictor of both the development and outcomes of DNS [12]. We found bilateral hiperintesities in the white matter on MRI scans, which may suggest worse prognosis.

We treated our patient with drugs potentially influencing the cognitive, motoric functions and affect (amantadine infusions, sertraline, levodopa, piracetam) with some improvement. In other observations drugs such as levodopa and anticholinergics were not effective [8]. There are initial reports of

bromocriptine alone or with levodopa to produce some beneficial effect [29]. There are opinions that stimulants, amantadine or levodopa, may be considered for lasting cognitive or parkinsonian symptoms [9]. Other authors found that early administration of erythropoietin improved neurological outcomes and reduced the incidence of DNS [30].

Another study demonstrated a neuroprotective strategy using the protocol for severe traumatic brain injury [31]. Early dexamethasone treatment may be useful for preventing DNS and may reduce serum MBP levels [32]. Potentially beneficial treatment methods may also be hypothermia and antioxidants such as N-acetylcysteine [33]. We suggest that these, as well as immunomodulating substances such as statins, be studied due to their pleiotropic properties [34].

In the presented case the EEG record was abnormal, which is consistent with other data indicating slowing in the EEG in 57% of patients with neurological symptoms [4].

In our patient there were hyperintense, diffused lesions of white matter with additional hyperintensities in semioval centres. There are similar descriptions of neuroimaging tests in other reports, such as bilateral white matter changes suggestive of demyelination with hypoperfusion in frontal regions detected in a ^{99m}Tc-ECD SPECT study. The MRI descriptions are as follows: globus pallidus lesions with periventricular deep white matter T2 signal, patchy areas of non-enhancing T1 isointense to mildly hyperintense, T2 and flair hyperintense signal changes over bilateral frontal and occipital subcortical, deep white matter and bilateral cerebral peduncles [22, 25].

Carbon monoxide intoxication causes damage in various areas of the cerebral white matter, but the semioval centre has been believed to be the main region responsible for neuropsychiatric symptoms [35]. Research using diffusion tensor imaging scans of MRI at different phases after CO poisoning has shown that fractional anisotropy changes in the semioval centre occur simultaneously with cognitive impairment or neurological symptoms. Two weeks after CO poisoning, in the subacute phase, patients with chronic symptoms had demyelinated white matter fibres in the semioval centres [36]. White matter in the semioval centre is the principal component of the frontal-subcortical pathway. White matter lesions, in particular of frontal-subcortical circuits, can lead to cognitive decline, and affect executive functions and working memory [37].

Acute CO poisoning causes damage to brain areas with great susceptibility to hypoxic injury, including the second and third cortical layers, watershed areas within the white matter, the basal ganglia, and the Purkinje cells of the cerebellum. The nature and distribution of brain lesions depend on the acuteness, severity, and the duration of exposure to CO. The neurological complications may be mediated by inflammatory and immune responses. There are different pathological effects and pathophysiological processes involved in the development of DNS after CO intoxication: injury of neurons of cortical layers III and V, decreased volume of the hippocampus, globus pallidus injury, Grinberg type demyelination of the white matter, loss of Purkinje cells in the cerebellum, oedematous necrosis, apoptosis, interruption of cellular respiration, and decreased glucose metabolism. The pathophysiological effects include increase in lactic acid, production of reactive oxygen species, over-reactivity of neuronal nitric oxide synthase, which produces nitrous oxygen, endothelial peroxynitrate deposition, decreased dopamine turnover in caudate nucleus, activation of the inflammatory cascade, peroxidation product malonlylaldehyde alters the ionic charge and configuration of myelin basic protein, inducing change in its antigenic nature, increased intracellular iron deposition, increased nitric oxide levels, P450 inhibition, increase of cytosol heme concentration, activation of genes mediating apoptosis, lipid peroxidation with degradation of unsaturated fatty acids leading to demyelination of CNS lipids and damage to myelin and axons [4, 38].

CONCLUSIONS

We presented the case of a patient with characteristic clinical findings as a result of CO poisoning. The symptoms of acute intoxication and the management in such cases is common knowledge, but the delayed neurological complications may still be misleading for clinicians, and are not fully known. Delayed neurological sequelae need further analyses, including histological processes aimed at the prevention or effective treatment of a disorder that is life-threatening and is characterized by significant psychomotor disability.

REFERENCES

1. Nieścior M, Jackowska T. Zatrucie tlenkiem węgla. Carbon monoxide intoxication. Post Nauk Med 2013;7:519-22.
2. Blumenthal I. Carbon monoxide poisoning. J R Soc Med 2001;94(6):270-2.
3. Statystyka interwencji straży pożarnej związanych z tlenkiem węgla. Komenda Główna Państwowej Straży Pożarnej. http://www.straz.gov.pl/porady/Sezon_grzewczy_2015_2016 (28.05.2016).
4. Betterman K, Patel S. Neurologic complications of carbon monoxide intoxication. Handb Clin Neurol 2014;120:971-9. doi: 10.1016/B978-0-7020-4087-0.00064-4.
5. Potocka-Banaś B, Borowiak K, Janus T, Majdanik S. Lawsuit experiment as an important element in expert's work. Ann Acad Med Stetin 2007;53 Suppl. 2:129–31.
6. Raub JA, Mathieu-Nolf M, Hampson NB, Thom SR. Carbon monoxide poisoning – a public health perspective. Toxicology 2000;145(1):1-14.
7. Choi IS. Delayed neurologic sequelae in carbon monoxide intoxication. Arch Neurol 1983;40(7):433-5.
8. Choi IS. Parkinsonism after carbon monoxide poisoning. Eur Neurol 2002;48(1):30-3.
9. Shprecher D, Mehta L. The syndrome of delayed post-hypoxic leukoencephalopathy. NeuroRehabilitation 2010;26(1):65-72.
10. Devine SA, Kirkley SM, Palumbo CL, White RF. MRI and neuropsychological correlates of carbon monoxide exposure: a case report. Environ Health Perspect 2002;110(10):1051-5.
11. Lee MS, Marsden CD. Neurological sequelae following carbon monoxide poisoning clinical course and outcome according to the clinical types and brain computed tomography scan findings. Mov Disord 1994;9(5):550-8. doi: 10.1002/mds.870090508.
12. Kuroda H, Fujihara K, Kushimoto S, Aoki M. Novel clinical grading of delayed neurologic sequelae after carbon monoxide poisoning and factors associated with outcome. Neurotoxicology 2015;48:35-43. doi: 10.1016/j.neuro.2015.03.002.
13. Schwartz A, Hennerici M, Wegener OH. Delayed choreoathetosis following acute carbon monoxide poisoning. Neurology 1985;35(1):98-9.

14. Bennetto L, Powter L, Scolding NJ. Accidental carbon monoxide poisoning presenting without a history of exposure: a case report. J Med Case Rep 2008;2:118. doi: 10.1186/1752-1947-2-118.
15. Fields RD. White matter in learning, cognition and psychiatric disorders. Trends Neurosci 2008;31(7):361-70. doi: 10.1016/j.tins.2008.04.001.
16. Smith EE, Salat DH, Jeng J, McCreary CR, Fischl B, Schmahmann JD, et al. Correlations between MRI white matter lesion location and executive function and episodic memory. Neurology 2011;76(17):1492-9. doi: 10.1212/WNL.0b013e318217e7c8.
17. Goulon M, Barois A, Rapin M, Nouailhat F, Grosbuis S, Labrousse J. Carbon monoxide poisoning and acute anoxia due to inhalation of coal gas and hydrocarbons: 302 cases, 273 treated by hyperbaric oxygen at 2 ata. Ann Med Interne (Paris) 1969;120(5):335-49.
18. Juurlink DN, Buckley NA, Stanbrook MB, Isbister GK, Bennett M, McGuigan MA. Hyperbaric oxygen for carbon monoxide poisoning. Cochrane Database Syst Rev 2005;1:CD002041. doi: 10.1002/14651858.CD002041.pub2.
19. Weaver LK, Hopkins RO, Chan KJ, Churchill S, Elliott CG, Clemmer TP, et al. Hyperbaric oxygen for acute carbon monoxide poisoning. N Engl J Med 2002;347(14):1057-67. doi: 10.1056/NEJMoa013121.
20. Buckley NA, Juurlink DN, Isbister G, Bennett MH, Lavonas EJ. Hyperbaric oxygen for carbon monoxide poisoning. Cochrane Database Syst Rev 2011;4:CD002041. doi: 10.1002/14651858.CD002041.pub3.
21. Sanders RW, Katz KD, Suyama J, Akhtar J, O'Toole KS, Corll D, et al. Seizure during hyperbaric oxygen therapy for carbon monoxide toxicity: a case series and five-year experience. J Emerg Med 2012;42(4):e69-72. doi: 10.1016/j.jemermed.2008.12.017.
22. Chan MY, Au TT, Leung KS, Yan WW. Acute carbon monoxide poisoning in a regional hospital in Hong Kong: historical cohort study. Hong Kong Med J 2016;22(1):46-55. doi: 10.12809/hkmj144529.
23. Kudo K, Otsuka K, Yagi J, Sanjo K, Koizumi N, Koeda A, et al. Predictors for delayed encephalopathy following acute carbon monoxide poisoning. BMC Emerg Med 2014;14:3. doi: 10.1186/1471-227X-14-3.
24. Pepe G, Castelli M, Nazerian P, Vanni S, Del Panta M, Gambassi F, et al. Delayed neuropsychological sequelae after carbon monoxide poisoning: predictive risk factors in the Emergency Department. A retrospective study. Scand J Trauma Resusc Emerg Med 2011;19:16. doi: 10.1186/1757-7241-19-16.
25. Bhatia R, Chacko F, Lal V, Mittal BR. Reversible delayed neuropsychiatric syndrome following acute carbon monoxide exposure. Indian J Occup Environ Med 2007;11(2):80-2. doi: 10.4103/0019-5278.34534.
26. Norkool DM, Kirkpatrick JN. Treatment of acute carbon monoxide poisoning with hyperbaric oxygen: A review of 115 cases. Ann Emerg Med 1985;14(12):1168-71.
27. Kuroda H, Fujihara K, Mugikura S, Takahashi S, Kushimoto S, Aoki M. Altered white matter metabolism in delayed neurologic sequelae after carbon monoxide poisoning: A proton magnetic resonance spectroscopic study. J Neurol Sci 2016;360:161-9. doi: 10.1016/j.jns.2015.12.006.
28. Ochudło S, Bal A, Opala G. Sequence of neurological symptoms in an early stage of acute carbon monoxide poisoning – a case report. Post Psychiatr Neurol 2000;9:207-12.
29. Tack E, de Reuck J. The use of bromocriptine in parkinsonism after carbon monoxide poisoning. Clin Neurol Neurosurg 1987;89(4):275-9.
30. Pang L, Bian M, Zang XX, Wu Y, Xu DH, Dong N, et al. Neuroprotective effects of erythropoietin in patients with carbon monoxide poisoning. J Biochem Mol Toxicol 2013;27(5):266-71. doi: 10.1002/jbt.21484.
31. Abdulaziz S, Dabbagh O, Arabi Y, Kojan S, Hassan I. Status epilepticus and cardiopulmonary arrest in a patient with carbon monoxide poisoning with full recovery after using a neuroprotective strategy: a case report. J Med Case Rep 2012;6:421. doi: 10.1186/1752-1947-6-421.
32. Li Q, Song JJ, Zhang HY, Fu K, Lan HB, Deng Y. Dexamethasone therapy for preventing delayed encephalopathy after carbon monoxide poisoning. Biotech Histochem 2015;90(8):561-7. doi: 10.3109/10520295.2015.1019565.
33. Oh S, Choi SC. Acute carbon monoxide poisoning and delayed neurological sequelae: a potential neuroprotection bundle therapy. Neural Regen Res 2015;10(1):36-8. doi: 10.4103/1673-5374.150644.
34. Kotlęga D, Ciećwież S, Turowska-Kowalska J, Nowacki P. Pathogenetic justification of statin use in ischaemic stroke prevention according to inflammatory theory in development of atherosclerosis. Neurol Neurochir Pol 2012;46(2):176-83.
35. Parkinson RB, Hopkins RO, Cleavinger HB, Weaver LK, Victoroff J, Foley JF, et al. White matter hyperintensities and neuropsychological outcome following carbon monoxide poisoning. Neurology 2002;58(10):1525-32.
36. Beppu T, Fujiwara S, Nishimoto H, Koeda A, Narumi S, Mori K, et al. Fractional anisotropy in the centrum semiovale as a quantitive indicato of cerebral white matter damage in the subacute chase in patients with carbon monoxide poisoning: correlation with the concentration of myelin basic protein in cerebrospinal fluid. J Neurol 2012;259(8):1698-705. doi: 10.1007/s00415-011-6402-5.
37. Huang LA, Ling XY, Li C, Zhang SJ, Chi GB, Xu AD. Study of white matter at the centrum semiovale level with magnetic resonance spectroscopy and diffusion tensor imaging in cerebral small vessel disease. Genet Mol Res 2014;13(2):2683-90. doi: 10.4238/2014.April.8.11.
38. Szpak GM, Lewandowska E, Modzelewska J, Stępień T, Kulczycki J. Delayed encephalopathy after carbon monoxide intoxication. Post Psychiatr Neurol 2010;19(4):330-31.